January 2017

Nuclear Material Events Database

Annual Report

Fiscal Year 2016

Prepared for the U.S. Nuclear Regulatory Commission
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Thomas W. Smith, INL
Dante C. Huntsman, INL
Robert L. Sant, INL

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Idaho National Laboratory
Risk Assessment and Management Services
Idaho Falls, Idaho 83415

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ABSTRACT

This report presents information on trending and analysis of incidents/accidents (events) reported to the Nuclear Regulatory Commission (NRC) that involve radioactive material. The events are reported by NRC licensees, Agreement States, and non-licensees, and are recorded in the NRC's Nuclear Material Events Database. The reported events are classified into categories based on event reporting requirements defined in Title 10 of the Code of Federal Regulations. The categories in this report are (1) Lost/Abandoned/Stolen Material, (2) Medical, (3) Radiation Overexposure, (4) Release of Licensed Material or Contamination, (5) Leaking Sealed Source, (6) Equipment, (7) Transportation, and (8) Other.

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ACRONYMS

ALARA	as low as reasonably achievable
ALI	annual limit on intake
AO	abnormal occurrence
CFR	Code of Federal Regulations
CT	computed tomography
DAC	derived air concentration
DDE	deep dose equivalent
DE	dose equivalent
EDE	effective dose equivalent
EQP	Equipment
EXP	Radiation Overexposure
FY	fiscal year
GTCC	greater than class C
HAZMAT	hazardous material
HDR	high dose rate
HLW	high-level waste
IAEA	International Atomic Energy Agency
INL	Idaho National Laboratory
LAS	Lost/Abandoned/Stolen Material
LDE	lens dose equivalent
LKS	Leaking Sealed Source
LS	least squares
MED	Medical
MRI	magnetic resonance imaging
NA	not applicable
NMED	Nuclear Material Events Database
NR	not recovered
NRC	Nuclear Regulatory Commission
NRCB	NRC Bulletin
ODOH	Ohio Department of Health
OTH	Other
PDEP	Pennsylvania Department of Environmental Protection
REAC/TS	Radiation Emergency Assistance Center/Training Site

RLM	Release of Licensed Material or Contamination
RSO	radiation safety officer
SDE	shallow dose equivalent
SNM	special nuclear material
SSE	error sum of squares
SSR	regression sum of squares
SST	total sum of squares
TEDE	total effective dose equivalent
TRS	Transportation

EXECUTIVE SUMMARY

The Nuclear Regulatory Commission's (NRC) Nuclear Material Events Database (NMED) contains records of events involving nuclear material reported to the NRC by NRC licensees, Agreement States, and non-licensees. The reported events are classified based on reporting requirements defined by Title 10 of the Code of Federal Regulations. The event reports are evaluated to identify statistically significant trends and events of higher significance (referred to as significant events in this report).

The significant events that occurred in Fiscal Year 2016 are summarized below. Note that a single event may be listed in more than one event type category.

Lost/Abandoned/Stolen Radioactive Sources/Material Events

Eleven significant events occurred involving the loss of 13 Category 1-3 sources as defined by the International Atomic Energy Agency's *Code of Conduct on the Safety and Security of Radioactive Sources (2004)*. Eight Category 2 sources and five Category 3 sources were lost; all of which were subsequently recovered. Note that one of the eight Category 2 sources was actually a shipment containing 23 sources (counted as a single source).

Regarding the eleven significant events:

- None of the 11 events involved Category 1 sources.
- Six of the 11 events involved the loss (and subsequent recovery) of Category 2 sources. Three of these events involved radiography devices; one device fell from a truck en route to a jobsite, one device was left at a jobsite, and one device was in a truck that was stolen. The other three events involved sources lost during shipping.
- Five of the 11 events involved the loss (and subsequent recovery) of Category 3 sources. All five of these events involved sources lost during shipping.

Medical Events

Seven significant events occurred, all of which were classified as potential Abnormal Occurrences. All seven of the events involved doses administered to wrong sites: three during Y-90 microsphere treatment, two during gamma knife treatment, one during high dose rate brachytherapy, and one during brachytherapy with a manual applicator.

In addition to the seven events above, two other significant events classified as potential Abnormal Occurrences occurred prior to Fiscal Year 2016 and were recently added to NMED. Both of these events involved doses administered to wrong sites: one during gamma knife treatment (eight patients affected) and one during prostate brachytherapy seed treatment.

Radiation Overexposure Events

Two significant events occurred. Both of the events involved radiographers that were exposed by unshielded radiography sources.

In addition to the two events above, one other significant event occurred prior to Fiscal Year 2016 and was recently added to NMED. This event also involved a radiographer exposed by an unshielded radiography source.

Release of Licensed Material or Contamination Events

No significant events occurred.

Leaking Sealed Source Events

One significant event occurred. In this event, at least one leaking I-125 brachytherapy seed was implanted into a patient during prostate treatment.

Equipment Events

Three significant events occurred. In the first event, a radiographer experienced difficulty fully retracting a radiography source into an exposure device, resulting in an overexposure to the radiographer. In the second event, the shutter of a fixed gauge came open during shipment, resulting in a significant package dose rate. In the third event, at least one leaking I-125 brachytherapy seed was implanted into a patient during prostate treatment.

In addition to the three events above, one other significant event occurred prior to Fiscal Year 2016 and was recently added to NMED. In this event, a gamma knife unit was misaligned during maintenance. Eight patients subsequently received doses to wrong locations.

Transportation Events

Two significant events occurred. Both of the events involved shipments of nuclear material (a gauge and a brachytherapy source) with shielding that became compromised, resulting in significant package dose rates.

Other Events

One significant event occurred, which was also classified as a potential Abnormal Occurrence. This event involved a dose to an embryo/fetus that resulted from the administration of I-131 to a pregnant patient.

Nuclear Material Events Database
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1. INTRODUCTION

1.1 Overview and Objectives

Nuclear material event reports are evaluated to identify statistically significant trends and significant events. The reported information aids in understanding why the events occurred and in identifying any actions necessary to improve the effectiveness of the nuclear material regulatory program.

A database for tracking nuclear material events was developed by the Nuclear Regulatory Commission (NRC) in 1981. In 1993, using existing material events databases, the NRC developed a new and more comprehensive database for tracking material events. This database, designated the Nuclear Material Events Database (NMED), contains records of events involving nuclear material reported to the NRC by NRC licensees, Agreement States, and non-licensees. The database is maintained by the Idaho National Laboratory (INL) and contains over 24,000 records of material events submitted to the NRC from January 1990 to present.

The events in this report are classified into the following categories based on event reporting requirements defined by Title 10 of the Code of Federal Regulations (CFR):

- Lost/Abandoned/Stolen Material (LAS),
- Medical (MED),
- Radiation Overexposure (EXP),
- Release of Licensed Material or Contamination (RLM),
- Leaking Sealed Source (LKS),
- Equipment (EQP),
- Transportation (TRS), and
- Other (OTH).

A description of categories addressed in this report and associated screening criteria are presented in Appendix A.

As noted above, this report provides trending information for events designated as "significant". Note that effective this report, *the category of fuel cycle events will no longer be included*. The NRC will continue to conduct trending of fuel cycle events in a separate process.

1.2 NMED Data

A single occurrence report may be captured in more than one NMED event category. For example, a report may describe a loss of licensed material that also resulted in a radiation overexposure. In such a case, both event categories are recorded in the NMED and identified by the same report number (referred to as an item number in the database).

The data presented in this report are limited to reportable events that occurred between October 1, 2006, and September 30, 2016. The data were downloaded from the NMED on January 5, 2017. Because the NMED is a dynamic database that is updated daily, variations in data may be encountered over time. Furthermore, even though many events were reported and entered in the database for operational experience purposes, only those events required to be reported by 10 CFR are addressed in this report.

This report displays annual trend data for each of the event categories for a 10-year period. A trend analysis was performed on each event category to identify the existence or absence of a statistically significant trend. If a statistically significant trend exists, the display indicates the direction and approximate rate of change with a trend line. For the purposes of this report, a statistically significant trend exists if the analysis indicates that the computed fit and slope of a least squares linear model is valid at a 95% confidence level. A primer on the statistical methods employed in the trend analysis is presented in Appendix B.

Note that the trending methodology is not normalized; the trend only considers the number of reported events and does not directly account for external issues such as changes to regulatory requirements or changes in the number of licensees. For example, an increasing trend in the number of medical events could be caused by an increase in the number of medical procedures being performed. Likewise, an event type showing a decreasing trend for NRC licensees and an increasing trend for Agreement State licensees could be caused by States becoming Agreement States (resulting in fewer NRC licensees and more Agreement State licensees).

Reporting guidance for Agreement States is provided in the *Handbook on Nuclear Material Event Reporting in the Agreement States*. The handbook is an appendix to the NRC Office of Nuclear Material Safety and Safeguards procedure SA-300, *Reporting Material Events*. Access to NMED is available to the staff of NRC, Agreement State, and Federal agencies at http://nmed.inl.gov.

For assistance on searches or other questions, contact Robert Sun (nmednrc@nrc.gov, 301-415-3421).

2. ANALYSIS OF NMED DATA

Event reports submitted to the NRC involving nuclear material are reviewed, categorized, and entered into the NMED. Charts are provided to display trends in annual data for the most recent 10-year period (FY07-16).

2.1 All NMED Events

Figure 1 displays the annual number and trend of NMED events that occurred during the 10-year period. The trend analysis determined that the NRC-regulated events represent a statistically significant decreasing trend (indicated by the trend line). However, the Total events and Agreement State-regulated events do not represent statistically significant trends (indicated by the absence of trend lines). Therefore, variations within the Total and Agreement State values represent random fluctuation around the average of the data.

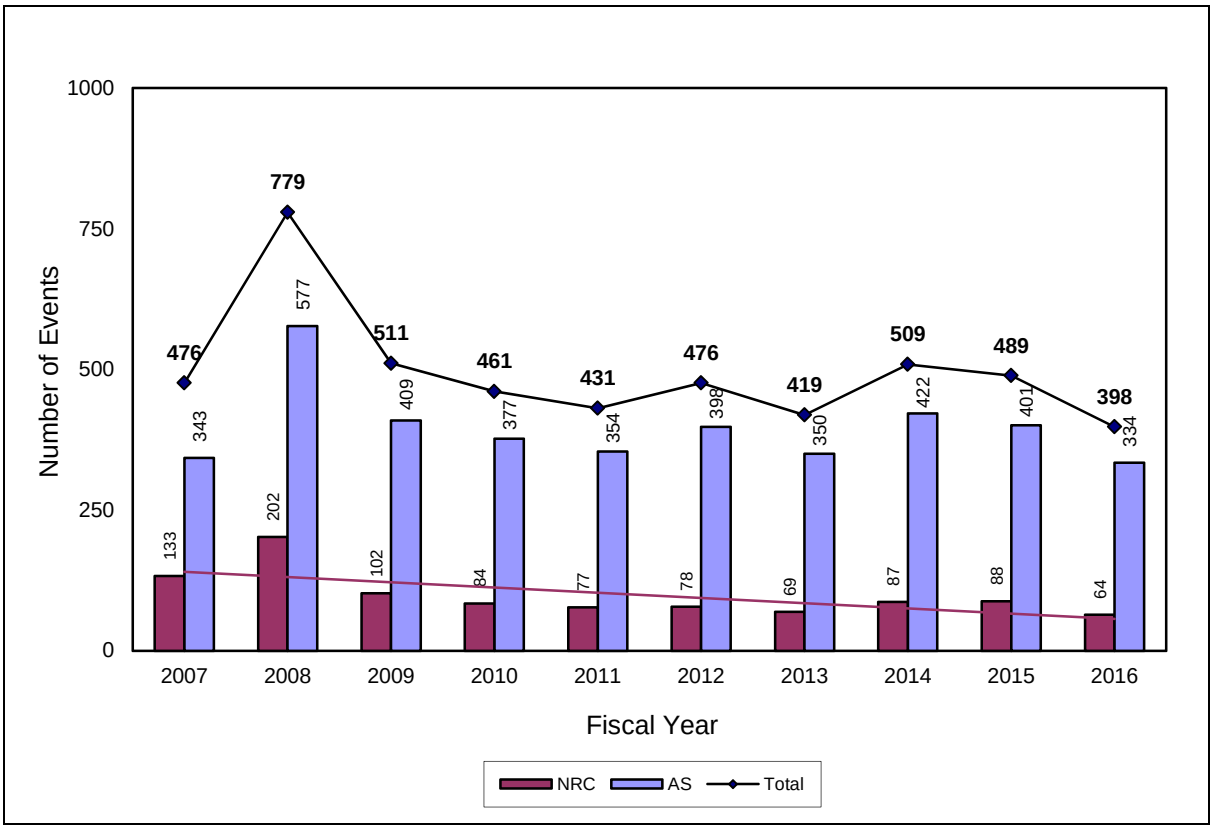

Figure 1. All NMED Events (4,949 total)

The following observations are made regarding the data in Figure 1.

- In FY16, 367 occurrences accounted for 398 events; a single occurrence can be classified in different event categories.
- The FY08 and FY09 data include 274 and 65 events respectively that resulted from Wal-Mart's one-time review of their tritium exit sign inventory.
- The most recent year's data are typically many records less than their final value when subsequent updates and late reports are received (see Appendix D, Figure D-1).
- The transition of states from NRC to Agreement State jurisdiction could result in increasing trends in Agreement State data and decreasing trends in NRC data.

Table 1 displays a summary of the trending analysis for all NMED event types included in this report. A more detailed discussion of the trending analysis results can be found in the section of this report devoted to each event type.

Table 1. Summary of Trending Analysis

Event Type	Total	NRC	Agreement State
All NMED Events	-	↘	-
Lost/Abandoned/Stolen Material (LAS)	↘	↘	-
Medical (MED)	-	-	-
Radiation Overexposure (EXP)	-	-	-
Release of Licensed Material or Contamination (RLM)	-	-	-
Leaking Sealed Source (LKS)	-	-	-
Equipment (EQP)	-	-	-
Transportation (TRS)	-	-	-
Other (OTH)	NA	NA	NA

Notes:

- ↗ indicates a statistically significant increasing trend.
- ↘ indicates a statistically significant decreasing trend.
- - indicates no statically significant trend.
- NA indicates that the data does not support trending analysis.

2.2 Lost/Abandoned/Stolen Material

2.2.1 Ten-Year Data

Figure 2 displays the annual number and trend of LAS events that occurred during the 10-year period. The trend analysis determined that the Total and NRC-regulated events represent statistically significant decreasing trends (indicated by the trend lines). However, the Agreement State-regulated events do not represent a statistically significant trend (indicated by the absence of trend line). Therefore, variations within the Agreement State values represent random fluctuation around the average of the data.

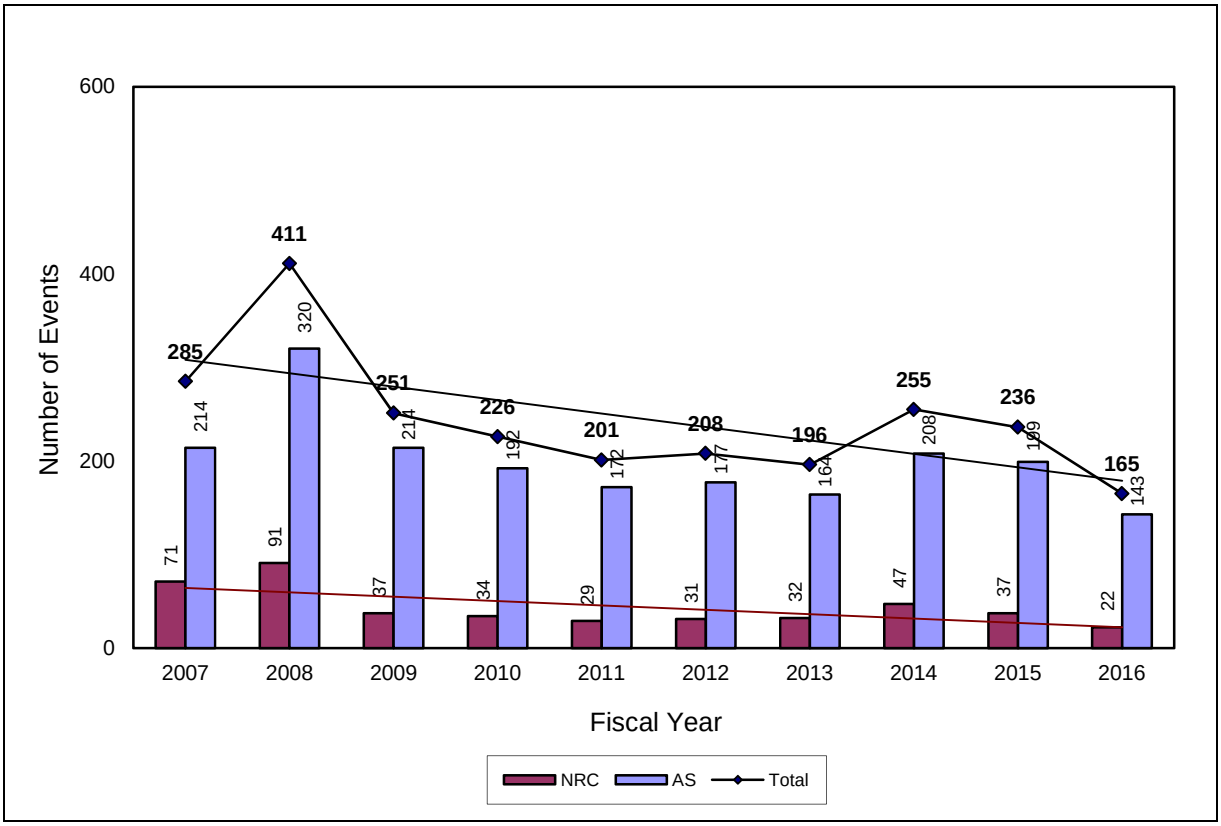

Figure 2. Lost/Abandoned/Stolen Material Events (2,434 total)

The FY08 and 09 data include 143 and 45 LAS events respectively that resulted from Wal-Mart's one-time review of their tritium exit sign inventory.

Appendix C contains a list of radionuclides derived from the International Atomic Energy Agency's (IAEA) *Code of Conduct on the Safety and Security of Radioactive Sources (2004)*. These radionuclides are grouped by the amount of radioactivity into five categories that correspond to the relative hazard, with Category 1 being the most hazardous.

For this report, IAEA Category 1 through 3 source events (excluding irretrievable well-logging source events) are considered significant. Regardless of IAEA category, events involving irretrievable well-logging sources are not considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

Table 2 displays the number of sources lost (approximately 4,004, excluding irretrievable well-logging sources) during the 10-year period and the number that have not been recovered (approximately 2,214), grouped by IAEA category where possible. These included two Category 1 sources, 52 Category 2

sources, and 36 Category 3 sources; all of which were recovered, with the exception of one Category 2 and three Category 3 sources.

Table 2. Number of Sources Lost/Abandoned/Stolen (LAS) and Sources Not Recovered (NR) - Excluding Irretrievable Well Logging Sources

Category		Fiscal Year 2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
1	LAS[4]	0	0	0	0	0	0	0	0	2	0	**2**
	NR[5]	0	0	0	0	0	0	0	0	0	0	**0**
2	LAS	2	11	2	0	2	3	10	5	9	8	**52**
	NR	0	0	0	0	1	0	0	0	0	0	**1**
3	LAS	1	3	1	4	4	7	3	4	4	5	**36**
	NR	0	0	0	1	0	1	0	0	1	0	**3**
4	LAS	57	71	50	76	44	44	24	53	43	37	**499**
	NR	17	35	25	27	23	14	9	26	19	18	**213**
5	LAS	70	129	76	89	82	83	69	87	79	73	**837**
	NR	19	57	20	29	11	25	7	33	31	46	**278**
< 5	LAS	2	0	2	1	1	0	1	1	1	1	**10**
	NR	0	0	2	1	0	0	0	0	1	1	**5**
Activity Not Known[1]	LAS	3	9	5	13	12	9	7	3	4	5	**70**
	NR	0	0	0	1	0	0	0	0	2	2	**5**
Nuclide Not Known[2]	LAS	2	0	0	0	6	0	1	0	1	0	**10**
	NR	0	0	0	0	5	0	0	0	1	0	**6**
Other[3]	LAS	276	460	274	182	209	193	174	329	191	200	**2488**
	NR	146	382	170	126	139	132	92	257	109	150	**1703**
Total	**LAS**	**413**	**683**	**410**	**365**	**360**	**339**	**289**	**482**	**334**	**329**	**4004**
	NR	**182**	**474**	**217**	**185**	**179**	**172**	**108**	**316**	**164**	**217**	**2214**

Notes:

1. The "Activity Not Known" category includes sources containing radionuclides listed in Appendix C for which the activity was not reported. Therefore, the sources were not included in Categories 1 through 5.
2. The "Nuclide Not Known" category includes those sources for which the radionuclide was not reported. Thus, the sources were not included in Categories 1 through 5 or Other.
3. The "Other" category includes sources containing radionuclides not included in Appendix C.

4. Events involving a larger number of sources are sometimes entered as a single source with an aggregate activity (for example, the loss of a container of brachytherapy seeds may be entered as a single source with a total combined activity).
5. Events involving the loss/theft of multiple sources may involve the recovery of only some of the sources and are entered as being partially recovered (rather than marking each source individually). The Category 1 through 3 "not recovered" source counts were corrected for the "partially recovered" source events.

Tables 3 and 4 provide more detail regarding the 10-year and current year "not-recovered" data highlighted in Table 2 in yellow and green, respectively. Table 3 displays radionuclide data pertaining to the IAEA Category 1 through 3 sources lost during the 10-year period that have not yet been recovered. The Decayed Activity values are conservative estimates in that the values are typically decayed from the loss date instead of the manufacturer's assay date. As a result, the actual decayed activities (based on the manufacturer's assay date) are likely less than the estimates. Table 4 is similar to Table 3, but limited to the current year.

Table 3. Summary of IAEA Category 1-3 Sources Not Recovered (FY07-16)

Radionuclide	Half-life[1]	Number of Sources Not Recovered[2,3]	Total Activity (Ci)	Total Decayed Activity (Ci)[4]	Total Decayed Activity IAEA Category
Ir-192	73.83 days	2	40.7	0.0	<5
Pu-238	87.7 years	2	5.3	5.2	3
Total		**4**	**46.0**	**5.2**	**3**

Notes:

1. Half-life values from the Chart of the Nuclides, 16th Edition.
2. Events involving a larger number of sources are sometimes entered as a single source with an aggregate activity (for example, the loss of a container of brachytherapy seeds may be entered as a single source with a total combined activity).
3. Events involving the loss/theft of multiple sources may involve the recovery of only some of the sources and are entered as being partially recovered (rather than marking each source individually). The source counts were corrected for the "partially recovered" source events.
4. The source activities were decayed from the event date to 1/5/2017 (data download date).

Table 4. Summary of IAEA Category 1-3 Sources Not Recovered (FY16)

Radionuclide	Half-life[1]	Number of Sources Not Recovered[2,3]	Total Activity (Ci)	Total Decayed Activity (Ci)[4]	Total Decayed Activity IAEA Category
		0			
Total		**0**			

Notes:

1. Half-life values from the Chart of the Nuclides, 16th Edition.
2. Events involving a larger number of sources are sometimes entered as a single source with an aggregate activity (for example, the loss of a container of brachytherapy seeds may be entered as a single source with a total combined activity).

3. Events involving the loss/theft of multiple sources may involve the recovery of only some of the sources and are entered as being partially recovered (rather than marking each source individually). The source counts were corrected for the "partially recovered" source events.
4. The source activities were decayed from the event date to 1/5/2017 (data download date).

2.2.2 FY16 Data

One hundred sixty-five LAS events occurred in FY16, seven of which involved irretrievable well logging sources. Excluding the irretrievable well logging sources, approximately 329 sources were lost/abandoned/stolen, 217 of which have not been recovered. Of the 329 lost sources, none were Category 1, eight were Category 2, and five were Category 3 sources; all of which were recovered.

Eleven of the FY16 LAS events were considered significant (involved Category 1-3 sources). Note that regardless of IAEA category, events involving irretrievable well logging sources are not considered significant.

Significant Events - Category 1 Source Events
None

Significant Events - Category 2 Source Events
Item Number 150616 - A radiography services company reported the theft and recovery of a radiography exposure device that contained a 2,738 GBq (74 Ci) Ir-192 source. On the morning of 11/19/2015, company personnel contacted the radiographer, who stated that he was coming to the facility. The radiographer did not show up and attempts to contact him were unsuccessful. The company contacted family members, interviewed coworkers, checked the job site, checked travel routes, and notified local law enforcement. The company recovered the truck and exposure device at 11:55 p.m. on 11/19/2015. The radiographer and a friend had taken the truck to a park from 10:00 a.m. to 9:30 p.m. and smoked synthetic marijuana in the front seat. The radiographer went to his father's residence at about 11:00 p.m. His father, who had been instructed to contact the company radiation safety officer (RSO) if he saw his son, took it upon himself to drive the truck and exposure device to the RSO's residence (five minutes away) at about midnight. The radiographer was fired. The company is holding meetings with their radiographers to discuss the incident and installing tracking devices on all trucks.

Item Number 150649 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 1,228.4 GBq (33.2 Ci) Ir-192 source. A radiographer and assistant completed work at a temporary jobsite on 12/11/2015 at a refinery in Canton, Ohio. They packed up and drove to their trailer. Shortly afterwards, they realized that they had left the exposure device at the jobsite. While enroute back to the jobsite, they received a phone call from the customer's project manager stating that they had found the unattended exposure device. The radiographers arrived and determined that the device was in the same placed they left it and it was locked. They estimated that the exposure device was unsecured for about 15 minutes. The radiographers surveyed the device, secured it in their vehicle, and traveled back to the trailer. The company performed an immediate safety stand down and stopped all radiographic operations. The involved radiographers were suspended pending investigation. On 12/14/2015, the RSO conducted an onsite visit and another safety meeting was held with all crews onsite.

Item Number 160126 - A common carrier reported the loss and recovery of a package (Type B, Transport Index of 1.2) that contained two Ir-192 radiography sources. One source contained 4.32 TBq (116.8 Ci) and the other source contained 4.18 TBq (113 Ci). On 3/16/2016, the package fell out of a transport vehicle onto a freeway in Houston, Texas. A member of the public found the package and called the source owner's phone number, which was on the package. The owner's RSO met with the member and recovered the package. The RSO performed a radiation survey and leak test. The package's outer shipping box was damaged, but the Type B container was in good condition and revealed negative leak test results. The sources were transported to the owner's facility and placed in storage. Investigation

revealed that the member of the public had the package for less than one hour. Exposure estimates for the member were less than 5 μSv (0.5 mrem). The common carrier employee failed to follow operating procedures for transporting dangerous goods. The carrier terminated his employment and provided additional instructions to personnel.

Item Number 160146 - A radioactive source manufacturer reported the loss and recovery of a shipment containing 23 radiography sources with a total activity of 73.17 TBq (1,977.6 Ci) of Ir-192. The manufacturer was notified by an air cargo company on 3/28/2016 that the package could not be located. The package was shipped on 3/23/2016 and scheduled to arrive in Prague, Czech Republic, on 3/28/2016. The air cargo company tracked the packaged from JFK Airport in New York, through Frankfort, Germany, to its arrival in Prague on 3/26/2016. The package was then declared to be missing. Investigation indicated that upon arrival in Frankfort, the pallet that the shipment was built on was offloaded from the aircraft and taken to a breakdown area to be rebuilt for shipment to Prague. The Federal Bureau of Investigation was notified. The air cargo company stated on 3/29/2016 that the shipment was located in Prague and arrangements were being made for final delivery.

Item Number 160169 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 3,651.9 GBq (98.7 Ci) Ir-192 source. The radiography crew failed to secure the device in their truck before leaving the company's facility on 4/13/2016. The crew left for a temporary jobsite with the device on the tailgate of the truck. The device subsequently fell from the truck. A member of the public found the device in the street at an intersection approximately 100 yards from the company's facility. The member of the public moved the device off of the street, into a ditch, and then contacted the company. The company immediately responded, recovered the device, and inspected it. No damage was identified and radiation surveys confirmed that the source was still fully shielded. The company estimated that the device was out of their control for approximately 13 minutes and stated that no person received a radiation exposure above limits. The involved radiographer received additional training on related procedures and will be required to work with a qualified radiographer for six months.

Item Number 160208 - A radiography equipment manufacturer reported the loss and recovery of two sources. On 9/4/2015, a radioactive source manufacturer shipped two drums (serial #63 and 68) to the equipment manufacturer. Each drum contained four special form capsules of Ir-192. Drum 63 had a total activity of 273.87 TBq (7,402 Ci), while drum 68 had a total activity of 290.3 TBq (7,846 Ci). Upon receipt, the drums were placed in storage until there was room in the hot cell to unload them. When the source serial numbers were transferred from the source manufacturer's technical data sheets to the equipment manufacturer's internal forms, only three of the four source serial numbers in each drum were listed (the past several shipments had only three sources in each drum). When the sources were removed from the drums in the hot cell, the three sources removed from each drum matched the recorded serial numbers. The drum lids were reattached in the hot cell. After removal from the hot cell, surveys of the drums failed to identify that one source remained within each drum. On 10/16/2015, the drums were returned to the source manufacturer via a common carrier, with drum 63 containing a 25.48 TBq (688.53 Ci) source and drum 68 containing a 26.19 TBq (707.92 Ci) source. The source manufacturer received the shipment on 10/21/2015 and found the sources within the drums on 10/22/2015. The equipment manufacturer's corrective actions included revising procedures to ensure that all sources are accounted for.

<u>Significant Events - Category 3 Source Events</u>

Item Number 160081 - A medical center reported the loss and recovery of a 173.9 GBq (4.7 Ci) Ir-192 brachytherapy source. The center was shipping the source to the source manufacturer via common carrier. The common carrier initially stated that the source could not to be shipped and that it was returned to the center. There was no date or time of return, and there was no required signature on file. The source was reported as missing on 2/17/2016. On 2/19/2016, the source manufacturer reported that they found the source. An administrative error resulted in the source being reported as missing.

Item Number 160130 - A radioactive source manufacturer reported the loss and recovery of a 473.6 GBq (12.8 Ci) Ir-192 brachytherapy source. The source was shipped to a medical center as an intended replacement source. The activity of the source actually exceeded the quantity that the center is licensed to possess. The manufacturer inadvertently shipped the wrong source to the center. An Ir-192 source with an activity of 414.4 GBq (11.2 Ci) should have been sent. When the center received the wrong source, they contacted manufacturer. The manufacturer's RSO responded to the center to replace the wrong source with the correct source. The RSO also packaged the wrong source and returned it to their facility via common carrier. The manufacturer stated that the error was caused by switching the source reference numbers following source calibration. They made changes to their standard operating procedure to ensure a source's calibrated activity is equal to or below the licensed activity. In addition, a second individual will be added to their calibration and labeling process.

Item Number 160306 - A member of the public in Waterford, Maine, reported that a radioactive package had been incorrectly delivered to their residence on or about 6/15/2016. The member contacted a hazardous material company, who contacted the Maine Radiation Control Program on 7/14/2016. The package was intact and contained a source exchanger that held a 247.9 GBq (6.7 Ci) Ir-192 source from Guatemala. During shipment, the package had fallen into a box/crate that contained a lawn mower, which was then delivered to the residence. The common carrier retrieved the package and will deliver it to the intended location (a radioactive source manufacturer). Dose reconstruction, package condition, and leak tests will be performed when the package arrives at the manufacturer.

Item Number 160318 - A radioactive source manufacturer reported the loss and recovery of a shipping package that contained a source changer, which held two Ir-192 sources. The sources had activities of 166.5 and 51.8 GBq (4.5 and 1.4 Ci). On 7/22/2016, the manufacturer was notified by the common carrier that the incoming package from Australia was unaccounted for. The missing package was located later that day at one of the common carrier's shipping hubs. The label had apparently fallen off the package. The package was expected to be delivered to the manufacturer on 7/29/2016.

Item Number 160344 - A medical center reported the loss and recovery of a 444 GBq (12 Ci) Ir-192 brachytherapy source. A common carrier was scheduled to deliver the source to the center on 6/20/2016. The source was not delivered. It was determined that carrier attempted to deliver the source on 6/20/2016 after normal business hours. The center assumed that the carrier would attempt to deliver the source again. The source manufacturer was notified and determined on 6/22/2016 that the source was being held at the carrier's distribution facility and would be delivered that day. The center's physics personnel are contractors. The carrier asked the contractor's office manager to pick up a dangerous goods package for the center. The manager picked up the package and called the center's chief physicist. The chief physicist determined that the package contained the missing Ir-192 source and told the manager to promptly return the package to the carrier. The carrier delivered the source to the center on 6/23/2016.

Events of Interest

Item Number 160096 - On 2/23/2016, a recycling facility in Ohio reported that shredded scrap metal from a recycling facility in Pennsylvania set off their radiation monitor alarms. The Ohio Department of Health (ODOH) and the Pennsylvania Department of Environmental Protection (PDEP) were notified. A large orphaned Ra-226 source of unknown activity is believed to have been shredded at the Pennsylvania facility on 2/22/2016. The damaged source contaminated shredded metal that was sent to two different Ohio recycling facilities. Contaminated shredded metal, which revealed exposure rates over 4 mSv/hour (400 mrem/hour), was isolated at the Ohio facility that reported the event. A locker room, clothes, vehicles, and workers were surveyed, with no contamination identified. However, the gloves of two workers were found to be radioactively contaminated. ODOH and PDEP responded to the other sites within their respective states. Radiation surveys are being performed of employees, vehicles, and equipment. This event was classified as an EQP, LAS, LKS, and RLM event.

Item Number 160300 - A recycling facility reported that a shipment of scrap metal set off their radiation monitor alarms on 7/11/2016. The Virginia Radioactive Material Program responded to the site to investigate the incident. A fixed nuclear gauge containing a 3.7 GBq (100 mCi) Cs-137 source was identified in the shipment. The source shutter was locked partially open, with the opening behind part of the gauge mounting. Maximum radiation levels on contact at the mounting near the shutter were 5 mR/hour, with less than 0.1 mR/hour at three feet. The gauge was placed into a drum using a mechanical hoist and the drum was placed in a secured area. Onsite tests for leakage indicated no removable contamination. The recycling facility arranged for proper disposal of the gauge. Exposure estimates indicated that no individual received more than 10 μSv (1 mrem) whole body or 50 μSv (5 mrem) extremity. The gauge manufacturer is reviewing their records to identify the gauge owner. This event was classified as an EQP and LAS event.

2.2.3 Events Recently Added to NMED That Occurred Prior to FY16

Eighteen LAS events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. None of these events was considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - Category 1 Source Events
None

Significant Events - Category 2 Source Events
None

Significant Events - Category 3 Source Events
None

Events of Interest
Item Number 140177 - A medical center reported the loss and recovery of a 7.88 MBq (213 μCi) I-125 localizing seed. A breast node localization procedure was performed on 1/23/2014 using two seeds; one seed implanted into a patient's right breast and one into the left breast. The seeds were thought to be excised on 2/7/2014. An audit conducted on 2/27/2014 of the surgical pathology's sample discovered that one seed was missing. Surgical records indicated that both seeds were excised and taken with the breast tissue samples to surgical pathology. The medical center believed that the seed was lost while in storage at surgical pathology. Radiation surveys were performed, but the seed was not found. On 3/30/2014, the missing seed was found still in the patient's right breast. The seed was removed from the patient on 4/1/2014, after residing in the patient 63 days longer than anticipated. The medical center maintains that the patient received 12.5 cGy (rad) to 250 g of breast tissue. The North Carolina Radioactive Materials Branch investigated the incident and determined that tissue at a 2.5 cm radius from the source received greater than 50 cSv (rem), tissue at 0.5 cm from the source received 2,200 cGy (rad), and the average dose received by tissue out to a radius of 4 cm (a volume of 270 cm^3) was approximately 50 cSv (rem). The patient also received external beam radiation treatment of between 300 and 1,100 cGy (rad) to the affected breast. The cause was determined to be human error. Corrective actions included modifying an existing procedure and generating a new procedure. This event was classified as an LAS and MED event.

Item Number 150289 - A medical waste company reported that biohazardous waste received from a medical center on 5/15/2015 contained I-131 therapy waste. The waste was an immediate concern, contaminating areas of the waste facility, resulting in the temporary closure of the facility. The medical center responded immediately to the waste facility, performed surveys, and confirmed that no waste facility personnel received more than minimal external exposure from the contamination. Radiation surveys identified hot spots in areas of general contamination as high as 30 mR/hour. A consultant was called and responded to the waste facility on 5/16/2015. Contaminated areas were remediated and the

facility was reopened after almost 48 hours. The consultant estimated that the waste contained less than 25.9 MBq (700 μCi) of I-131. When the waste was returned to the medical center, they confirmed that the waste originated from their facility and estimated that the waste contained 62.9 MBq (1.7 mCi) of I-131. The medical center's investigation revealed that the radiation detectors placed in areas where medical waste was packaged for offsite transport were possibly disregarded by medical center or waste facility employees who moved the waste past the detectors. The detectors were found to be inoperable on the morning of 5/15/2015, but were promptly restored to service. Corrective actions included suspending waste shipments until this event was understood, retraining personnel, adding additional physical security measures, installing video equipment in the waste area, and installing cages around the radiation detection equipment to prevent the detectors from being unplugged or rendered inoperable. This event was classified as an LAS and RLM event.

Item Number 150461 - On 8/4/2015, a recycling facility notified the Alabama Office of Radiation Control that they had contaminated items that needed to be transferred to a radioactive waste broker. On 8/4 and 8/7/2015, Alabama personnel visited the facility to investigate the items. Three 55-gallon drums contained pipe contaminated with naturally occurring radioactive material; the highest reading on the outside of the drums was 1.4 mR/hr. There was also a manifold containing Th-232 with a reading of 0.75 mR/hr. The last item was a damaged and rusty gauge without a shutter. The gauge contained a Sr-90 source and read 1,500 mR/hour (beta/gamma) and 300 mR/hour (gamma) at the port opening. There were no identifying marks on the gauge and the owner was unknown. A leak test was performed. The gauge was secured and placed into storage at the recycling facility pending disposal. A radioactive waste broker picked up the gauge/source on 1/12/2016 under the orphan source program. The source was estimated to contain a Sr-90 activity of 1,850 MBq (50 mCi). This event was classified as an EQP and LAS event.

Item Number 160014 - A radiopharmacy reported delivering a package containing 9,694 MBq (262 mCi) of Tc-99m to the wrong customer in Santa Fe, New Mexico. The package was left in the wrong customer's parking lot at 7:07 a.m. on 4/28/2015. The package was left unattended for up to 18 minutes and then retrieved by the wrong customer. The radiopharmacy performed worst case exposure estimates for members of the public and occupational workers, which revealed a maximum exposure of less than 0.5 μSv (0.05 mrem). The package was subsequently picked up and delivered to the correct customer. Corrective actions to prevent recurrence included providing additional training to personnel.

2.3 Medical

2.3.1 Ten-Year Data

Figure 3 displays the annual number and trend of MED events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

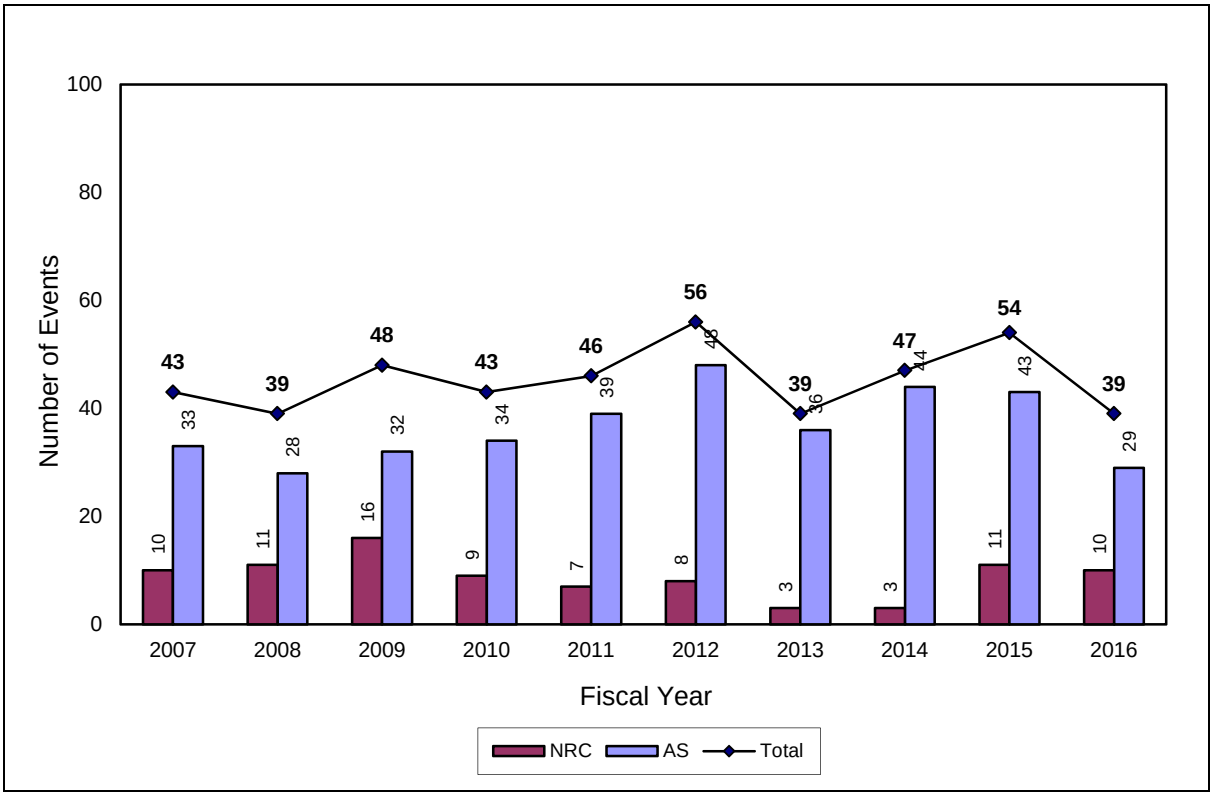

Figure 3. Medical Events (454 total)

Table 5 lists the number of MED events that were classified as Abnormal Occurrences (AOs) in NUREG-0090, *Report to Congress on Abnormal Occurrences*. Table 5 also includes events involving doses to an embryo/fetus or a nursing child (reportable per 10 CFR 35.3047). By definition, these events are not medical events (reportable per 10 CFR 35.3045) and are captured in NMED as an "Other" event. However, they are included here for reference.

Table 5. Medical and Embryo/Fetus or Nursing Child AO Events

	Fiscal Year										
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total[1]**
Medical	11	12	15	12	14	13	7	11	14	7	**116**
Embryo[2]	2	2	2	2	1	1	2	1	1	1	**15**
Total	**13**	**14**	**17**	**14**	**15**	**14**	**9**	**12**	**15**	**8**	**131**

Notes:

1. Events are marked as potential AOs until they complete the NRC's formal AO determination process and are reported in NUREG-0090. Potential AOs are included in this table.
2. Includes doses to an embryo/fetus or a nursing child reportable per 10 CFR 35.3047.

For this report, events classified as AOs (or potential AOs) are considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.3.2 FY16 Data

Thirty-nine MED events occurred in FY16, seven of which were considered significant.

Significant Events - AOs or Potential AOs

Item Number 150550 - A patient with trigeminal neuralgia received a gamma knife treatment to the wrong site on 10/1/2015. The incident involved a stereotactic radiosurgery unit and 162.32 TBq (4,387 Ci) of Co-60. The patient was prescribed to receive 8,500 cGy (rad) to a site in the right side of the brain at the 100% isodose line, but instead received the treatment to the left side of the brain. The 80% isodose line was approximately 33.5 cubic mm and was prescribed to receive 6,800 cGy (rad). The incident was identified as the treatment was completed. The incident was reviewed, discussed, and confirmed by the involved medical personnel. The medical center determined that the isocenter was positioned incorrectly due to human error. The patient was notified of the event by the attending neurosurgeon on 10/1/2015 and then received the correct treatment later that same day. The attending radiation oncologist notified the referring physician. North Carolina personnel performed an onsite investigation on 10/5/2015. Corrective actions included procedure modifications.

Item Number 160040 - A patient received a high dose rate brachytherapy treatment to the wrong site. The patient received three treatment fractions in November 2015. In December 2015, the patient reported to her primary care physician with burns on her leg. The authorized user was notified of the event in December and the authorized medical physicist and RSO were notified of the event on 1/19/2016. The medical center believes that the incident occurred during the second treatment fraction performed on 11/9/2015. The prescribed dose to the intended treatment site was 6,000 cGy (rad), but that dose was inadvertently delivered to the patient's leg. The preliminary cause is human error with the transfer tube/applicator interface. The medical center is conducting an internal investigation. The Colorado Department of Health is also investigating the incident.

Item Number 160077 - A patient with brain metastases received a gamma knife treatment to the wrong site on 2/15/2016. The event involved the use of a new frame adaptor. The frame adapter is the device that clamps onto the head frame in order to properly position and restrain the patient's head in the gamma knife unit. The gamma knife unit contained Co-60 sources with a maximum total activity of 407 TBq (11,000 Ci). The patient was receiving treatment to 14 sub-centimeter brain metastases. One lesion was prescribed 1,200 cGy (rad), one lesion was prescribed 1,800 cGy (rad), and 12 lesions were prescribed 2,100 cGy (rad). Following treatment to six of the 14 sites, the patient was given a break. The authorized user and authorized medical physicist entered the room to release the patient from the restraining device and assist her to the rest room. They noted that the frame adapter was locked, but not in the correct position. The displaced distance was measured at a maximum of 2 cm in the direction of one plane, resulting in the patient receiving unintended radiation dose to normal brain tissue. Four non-target sites received 2,100 cGy (rad), one non-target site received 1,800 cGy (rad), and one non-target site received 1,200 cGy (rad). The patient, patient's family, and referring physician were informed of the event on 2/15/2016. After re-aligning the frame adaptor, it was determined by all parties to continue treatment of the remaining eight lesions; the medical team will review treatment of the six untreated lesions at a later time. The medical center thought that the frame adapter could not be locked on the head frame unless it was in the proper position. The gamma knife equipment manufacturer was contacted and responded to

investigate. A root cause analysis was performed. The cause was attributed to a combination of three failures; a non-keyed design resulting in the possibility to place the frame adaptor onto the head frame incorrectly, a discrepancy in the clamping force between the old and new frame adapters, and instructions not followed by the operator resulting in a large deviation. The medical center treated eight patients with the new frame adaptor prior to this event. The adaptor may have been misaligned during those treatments. The patients will be evaluated for a period of at least three years. Actions to prevent recurrence included requiring a medical physicist, nurse, and authorized user to position and secure the frame adaptor, requiring the adaptor be secured while the patient is sitting for better visibility, and developing a new pretreatment checklist to be executed by gamma knife nursing, physics, and an authorized user. Additional training was developed for all required staff. The manufacturer will send a note to all customers using the new frame adapter of the risks of misalignment when docking the adapter.

Item Number 160185 - A patient received 3.28 GBq (88.65 mCi) of Y-90 microspheres to an incorrect segment of the liver. The patient had hepatocellular carcinoma and was prescribed to receive treatment to segments V, VI, VII, and VIII (right lobe) of the liver, with an estimated treatment volume of 1,290 ml. However, during treatment on 4/27/2016, the catheter moved (due to patient movement or breathing) and the microspheres were administered to a medial portion of segment IV (left lobe), with an estimated administered volume of 330 ml. The prescribed dose was 12,000 cGy (rad) to the segments in the right lobe, but segment IV received approximately 11,850 cGy (rad), as determined by Bremmstrahlung imaging. A medical consultant subsequently determined that segment IV received 43,700 cGy (rad). Segment IV was previously treated on 1/27/2016 and there was some residual cancer. The patient and referring physician were notified and the patient was rescheduled for treatment of segments V, VI, VII, and VIII at a later date. The administration procedure requires fluoroscopic imaging with a contrast agent immediately prior to connecting the microsphere treatment device to verify catheter position, but this step was not performed. Hepatic and tumor necrosis are anticipated due to this event. Corrective actions included procedure modification to ensure that the catheter position is properly verified.

Item Number 160228 - A patient receiving treatment for carcinoma only received 1,500 cGy (rad) on 5/27/2016, instead of the prescribed 3,460 cGy (rad) to the target tissue. The treatment plan involved a tandem and ovoid applicator and Cs-137 sealed sources. The lower rectum and vaginal areas received more dose than expected, but were believed to be within tolerance. The bladder and mid-rectum received less incidental exposure than expected. The cause of the event was determined to be human error. The applicator tube used to place the source into the left side of the tandem had become crimped by the lead pig during transport to the patient's room. The resident physician and medical physicist stated that resistance felt during the application process led them to believe that the source was fully deployed to the end of the tube, but it was not.

Item Number 160253 - A patient received a Y-90 microsphere dose that was 88.6% more than prescribed on 6/16/2016. In addition to the incorrect activity, the incorrect liver lobe was treated. The patient received 4.02 GBq (108.6 mCi) of Y-90, which resulted in a liver dose of 32,800 cGy (rad). The patient was prescribed a dose of 12,000 cGy (rad) to a different lobe of the liver. The administered microspheres were intended for another patient's treatment scheduled for 6/17/2016. The patient was notified of the error and the medical center investigated the event. The cause of the event was inadequate procedures and insufficient training. The cause of the treatment to the wrong lobe of the liver was displacement of the catheter and failure to verify its position during administration. Corrective actions included developing and implementing a formal standard operating procedure for microsphere treatments, implementing multiple visual and written verifications, and incorporating additional imaging techniques to verify catheter placement.

Item Number 160284 - A patient’s written directive was not followed during a hepatic Y-90 microsphere treatment administered on 5/19/2016. The error was discovered during a subsequent review of the patient’s records in preparation for an additional hepatic treatment scheduled for 6/16/2016. The 5/19/2016 written directive prescribed radioembolization of the patient’s right hepatic lobe with an

activity of 1,076.7 MBq (29.1 mCi) for a dose of 3,213 cGy (rad). However, that treatment was delivered to the left hepatic lobe, during which stasis was reached after administering 868.76 MBq (23.48 mCi) and a resulting dose of 5,177 cGy (rad). During preparation for treatment of the left hepatic lobe on 6/16/2016, it was discovered that the 5/16/2016 treatment had been administered to the left lobe. The left hepatic lobe actually received 119.4% of the activity prescribed in the written directive scheduled for 6/16/2016, which listed 727.79 MBq (19.67 mCi) and a dose of 4,337 cGy (rad). The patient's right hepatic lobe was treated under a revised written directive on 6/16/2016. The patient was informed of this event on 7/5/2016. This event was caused by the failure to follow procedures. Procedure modifications were incorporated and each member of the team received instruction. The medical center is tracking the event in their internal risk management system for further review and potential improvements to their program.

Events of Interest

Item Number 160387 - A patient received a skin exposure that exceeded 50 cSv (rem) on 9/1/2016 during an injection procedure involving Tc-99m. A leak occurred in the delivery system, resulting in skin contamination. A dose containing 1,073 MBq (29 mCi) was ordered for the patient's bone scan. While injecting the dose into the patient's intravenous port, the technologist noticed leakage and immediately stopped the procedure. The patient's arm was wiped and cleaned with gauze several times. The medical center estimated the patient's skin contamination from residual activity at approximately 584.6 MBq (15.8 mCi).

Embryo/Fetus or Nursing Child Dose Events - AOs or Potential AOs

Doses to an embryo/fetus or nursing child are reportable per 10 CFR 35.3047. By definition, these events are not medical events (reportable per 10 CFR 35.3045) and are captured in NMED as "Other" events. However, it is appropriate to also discuss these events in this section. One of these events occurred in FY16 and was classified as a potential AO.

Item Number 160366 - A pregnant patient received a thyroid ablation treatment on 7/13/2016. The prescribed dosage was 2.78 GBq (75 mCi) of I-131 and the patient received 2.89 GBq (78 mCi). Subsequently, the patient became aware that she was pregnant at the time of the procedure and informed the medical center on 8/16/2016. Fetal gestation at the time of the treatment was estimated to be nine days post conception. The RSO estimated an exposure to the embryo/fetus of approximately 20 cGy (rad). The patient was administered a pregnancy test prior to treatment and the results were negative. The medical center stated that the incident was a result of patient non-compliance because she was instructed not to have sexual contact prior to the administration.

2.3.3 Events Recently Added to NMED That Occurred Prior to FY16

Four MED events and no embryo/fetal dose events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. Two of the MED events were considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - AOs or Potential AOs

Item Number 150140 - A medical center reported eight medical events involving a gamma knife unit that contained 244.2 TBq (6,600 Ci) of Co-60. Five of the events exceeded the NRC's Abnormal Occurrence criteria. The patients were being treated for acoustic neuromas and metastatic tumors in the brain. All eight patients received their prescribed doses, ranging from 1,300 to 2,400 cGy (rad), to the wrong location due to misalignment of the patient positioning system. This misalignment occurred during maintenance of the unit between 12/13/2014 and 1/1/2015 by the gamma knife unit manufacturer, which resulted in the patient positioning system being off-target by 1.87 mm. The eight patient treatments were performed between 1/7/15 and 2/12/2015. All of the patients and referring physicians were notified. The effects to the patients are still being determined. The cause of the misalignment of the patient positioning

system was the failure to use the correct service procedures during maintenance. Corrective actions include the development of a new set of tests to verify patient positioning. This event was classified as an EQP and MED event.

Item Number 150552 - A patient received an I-125 brachytherapy prostate seed implant procedure on 8/21/2015. A computed tomography (CT) scan performed on 9/23/2015 and a post implant study on 10/1/2015 revealed that the seeds were not adequately placed in the prostate. The seeds had a total activity of 644.8 MBq (17.427 mCi). The implant procedure was performed using ultrasound, but the images were confusing. It was determined that the prostate received less than 80% of the prescribed dose and a large part of the prostate gland was not treated. The prostate was prescribed 14,500 cGy (rad). The medical center investigated the radiation dose received by other tissues, such as the rectum. A magnetic resonance imaging (MRI) scan was scheduled to better visualize the implant area. The cause was determined to be human error. Corrective actions included a new quality management plan, a new written procedure, and additional personnel training. The Ohio Department of Health sent an inspector to the medical center for further investigation. It was concluded that no activity was administered to the prostate gland, but that the seeds had been implanted into a mass that was mistakenly identified as the prostate gland.

Events of Interest

Item Number 140177 - A medical center reported the loss and recovery of a 7.88 MBq (213 μCi) I-125 localizing seed. A breast node localization procedure was performed on 1/23/2014 using two seeds; one seed implanted into a patient's right breast and one into the left breast. The seeds were thought to be excised on 2/7/2014. An audit conducted on 2/27/2014 of the surgical pathology's sample discovered that one seed was missing. Surgical records indicated that both seeds were excised and taken with the breast tissue samples to surgical pathology. The medical center believed that the seed was lost while in storage at surgical pathology. Radiation surveys were performed, but the seed was not found. On 3/30/2014, the missing seed was found still in the patient's right breast. The seed was removed from the patient on 4/1/2014, after residing in the patient 63 days longer than anticipated. The medical center maintains that the patient received 12.5 cGy (rad) to 250 g of breast tissue. The North Carolina Radioactive Materials Branch investigated the incident and determined that tissue at a 2.5 cm radius from the source received greater than 50 cSv (rem), tissue at 0.5 cm from the source received 2,200 cGy (rad), and the average dose received by tissue out to a radius of 4 cm (a volume of 270 cm^3) was approximately 50 cSv (rem). The patient also received external beam radiation treatment of between 300 and 1,100 cGy (rad) to the affected breast. The cause was determined to be human error. Corrective actions included modifying an existing procedure and generating a new procedure. This event was classified as an LAS and MED event.

Embryo/Fetus or Nursing Child Dose Events - AOs or Potential AOs

None

2.4 Radiation Overexposure

2.4.1 Ten-Year Data

Figure 4 displays the annual number and trend of EXP events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

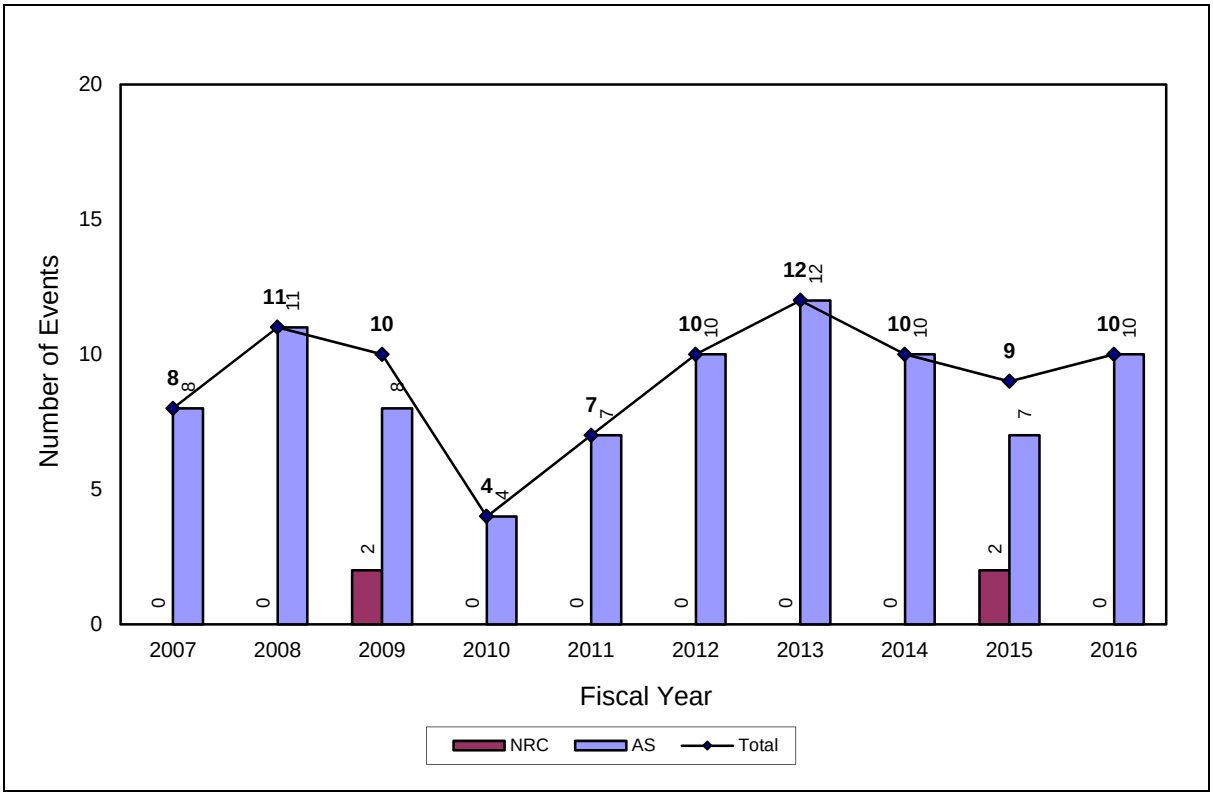

Figure 4. Radiation Overexposure Events (91 total)

The significance of individual EXP events may be determined by the CFR reporting requirement applicable to the event. For example, an event that is required to be immediately reported is typically more significant than an event with a 30-day reporting requirement. For this report, events requiring immediate or 24-hour reporting are considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

Table 6 displays the number of events based on the different reporting requirement time categories. Note that each event is counted only once. If an event involved exposures that were reportable in more than one category, the event is counted in only the most restrictive category.

Table 6. EXP Events Classified by CFR Reporting Requirement

	Fiscal Year										
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Immediate	1	0	0	0	1	1	0	0	0	1	**4**
24-Hour	1	3	1	1	0	4	1	3	4	1	**19**
30-Day	6	8	9	3	6	5	11	7	5	8	**68**
Total	**8**	**11**	**10**	**4**	**7**	**10**	**12**	**10**	**9**	**10**	**91**

2.4.2 FY16 Data

Ten EXP events occurred in FY16, two of which were considered significant.

Significant Events - Immediate Reporting

Item Number 160203 - A radiographer received a radiation overexposure during operations on 5/11/2016. The source guide tube and collimator fell from a jig it had been taped to while the 1,287.6 GBq (34.8 Ci) Ir-192 source was extended. The radiographer failed to retract the source into the exposure device before he walked to the end of the guide tube, picked it up, and taped it back onto the jig. The radiographer's dosimetry was sent for immediate processing. The radiography services company completed a re-enactment of the incident using video and an empty exposure device with attachments. The re-enactment demonstrated that the radiographer placed his left hand on the collimator and inserted his middle finger into its port hole. The RSO completed exposure calculations of 467 cGy (rad) to the finger. Dosimetry badge results revealed a whole body exposure of 9.37 mSv (937 mrem). That badge was worn for eight days during the month. The radiographer's finger appeared to show slight reddening; otherwise no visible effects were identified. Bloodwork was completed with no unusual results. The Texas Department of State Health Services investigated the incident and concurred with exposure results for the radiographer. The corporate RSO sent out an alert to remind personnel to be safety cautious. The company terminated the involved radiographer's employment. As of 6/10/2016, this incident had a final International Nuclear Event Scale rating level of 2.

Significant Events - Within 24-Hour Reporting

Item Number 150607 - A radiographer received a radiation overexposure during operations on 11/11/2015. He stated that he cranked out the 4,588 GBq (124 Ci) Ir-192 source, waited the appropriate time for the radiograph, and cranked the source back in. However, he failed to fully retract the source. When he retrieved the film, he noticed that his survey meter was pegged off scale. He went to his truck and checked his pocket dosimeter, which was also off scale. He then picked up the crank assembly and fully retracted the source into the radiography exposure device, which took about one quarter of a turn. He informed his supervisor that night and his monitoring badge was sent for processing. The results revealed 11.345 cSv (rem) DDE and 11.494 cSv (rem) LDE. The Texas Department of State Health Services investigated the incident and confirmed that the radiographer had not touched the source port on the exposure device while the source was unshielded. Exposure reports revealed a 2015 DDE exposure to the radiographer of 12.167 cSv (rem). Blood work was analyzed by the Radiation Emergency Assistance Center/Training Site (REAC/TS) and revealed no discernable differences compared to a normal blood sample. Corrective actions included removing involved personnel from duties involving radiation exposure, providing additional training to personnel, and providing improved supervision to personnel. As of 11/16/2015, this incident had a final International Nuclear Event Scale rating level of 2. This event was classified as an EQP and EXP event.

Events of Interest

Item Number 160186 - A copper mining company reported that 18 employees received radiation exposure from a fixed nuclear gauge, which contained a 3.52 GBq (95 mCi) Cs-137 source. The source originally

contained an activity of 5.55 GBq (150 mCi). The gauge was mounted on the chute above an ore crusher that was being worked on. Employees worked in the area of concern from 4/23 through 4/26/2016, when the RSO became aware of the incident. The cause of the event was determined to be failure to follow procedures. The work supervisor admitted to not locking the gauge out of service during work operations. The radiation exposure for each employee was calculated using very conservative estimates that assumed each employee was standing directly in the radiation beam for the entire duration they were in the ore crusher. Two employees received 187 mR, two received 112 mR, five received 75 mR, two received 47 mR, and seven received 23 mR. Corrective actions included reviewing and revising lock out procedures, assigning the lock out task to one department, and requiring personnel review yearly training on radiation sources. In addition, the company will evaluate the location of all warning signs and investigate other gauging options that do not employ radiation sources.

Item Number 160355 - Three members of the public were exposed to radiation during radiography operations at a water tower on 6/22/2016. The radiography exposure device contained an 854.4 GBq (23.2 Ci) Ir-192 source. The radiographer and assistant radiographer determined that a Bosun's chair was needed to secure the radiographic film to the inside of the water tower. Because the radiography team had no experience with a Bosun's chair, the water tower's contractor accepted responsibility to position the film. Following equipment setup for the 10th exposure, the radiographer extended the source for an exposure time of seven minutes and 10 seconds. After six minutes and 30 seconds, two contractor employees walked from around the water tower. The radiographer retracted the source and secured it in the exposure device. It was determined that Employee A had been in the Bosun's chair next to the 1 1/16 inch thick steel plate approximately 18 to 24 inches from the exposed radiography source. Employee B had been on a ladder approximately 10 feet away. Employee C had been on the ground approximately 35 feet from the exposed source. Investigation revealed that Employee A was in the Bosun's chair for about four minutes and 15 seconds before climbing down the ladder and exiting the tower. Employee A's whole body exposure was calculated to be 8.71 mSv (871 mrem). Employee B's and Employee C's whole body exposures were calculated to be 260 and 9.5 μSv (26 and 0.95 mrem), respectively. The radiography services company wrote a new procedure to follow when radiography operations require the assistance of members of the public. Involved radiography staff was provided retraining. The incident and corrective actions will be reviewed with other personnel during the next annual refresher training.

Item Number 160370 - A radiographer received a radiation overexposure. The radiographer's dosimeter received 5.5 cSv (rem) during the July 2016 monthly monitoring period. That exposure resulted in a total yearly exposure of 6.4 cSv (rem). The RSO investigated the cause of the incident and determined that the radiographer had not been following procedures. The radiographer had been working in an enclosed area and had not distanced himself from the 3,589 GBq (97 Ci) Ir-192 source as required. Subsequent interviews with the company and both radiographers on the job indicated that the daily survey sheets had been falsified and that the overexposed radiographer had taken a calculated risk of extra exposure in order to produce work more quickly. Both radiographers were terminated. As of 10/4/2016, this incident had a final International Nuclear Event Scale rating level of 2.

2.4.3 Events Recently Added to NMED That Occurred Prior to FY16

Four EXP events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. One of these events was considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - Immediate Reporting
None

Significant Events - Within 24-Hour Reporting

Item Number 160272 - A radiographer received a radiation overexposure during operations on 5/6/2015. While performing the last shot of the day, the radiographer was adjusting the source collimator when the customer's quality control person called over the radio. The radiographer assistant (on the same radio channel) interpreted the radio call as direction to crank out the 2.59 TBq (70 Ci) Ir-192 source. When the radiographer felt the vibration of the source being cranked out, he dropped the collimator, exited the area, and retracted the source into the exposure device. The radiography services company contacted a consultant and the Radiation Emergency Assistance Center/Training Site (REAC/TS) for consultation on the incident. Using badge processing results and worst case scenario calculations, they were able to determine that the radiographer received an extremity exposure between 500 and 1,000 mGy (50 and 100 rad). The radiography services company continued to monitor the radiographer's hands until 6/20/2015. Periodically, pictures of his hands were documented for possible signs of radiation exposure; none were noted. The radiographer's year-to-date DDE was 2.62 mSv (262 mrem). The root cause was determined to be communication weakness. All company employees were informed of the incident and reminded of the importance of a visual confirmation prior to exposing the source.

Events of Interest

None

2.5 Release of Licensed Material or Contamination

2.5.1 Ten-Year Data

Figure 5 displays the annual number and trend of RLM events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

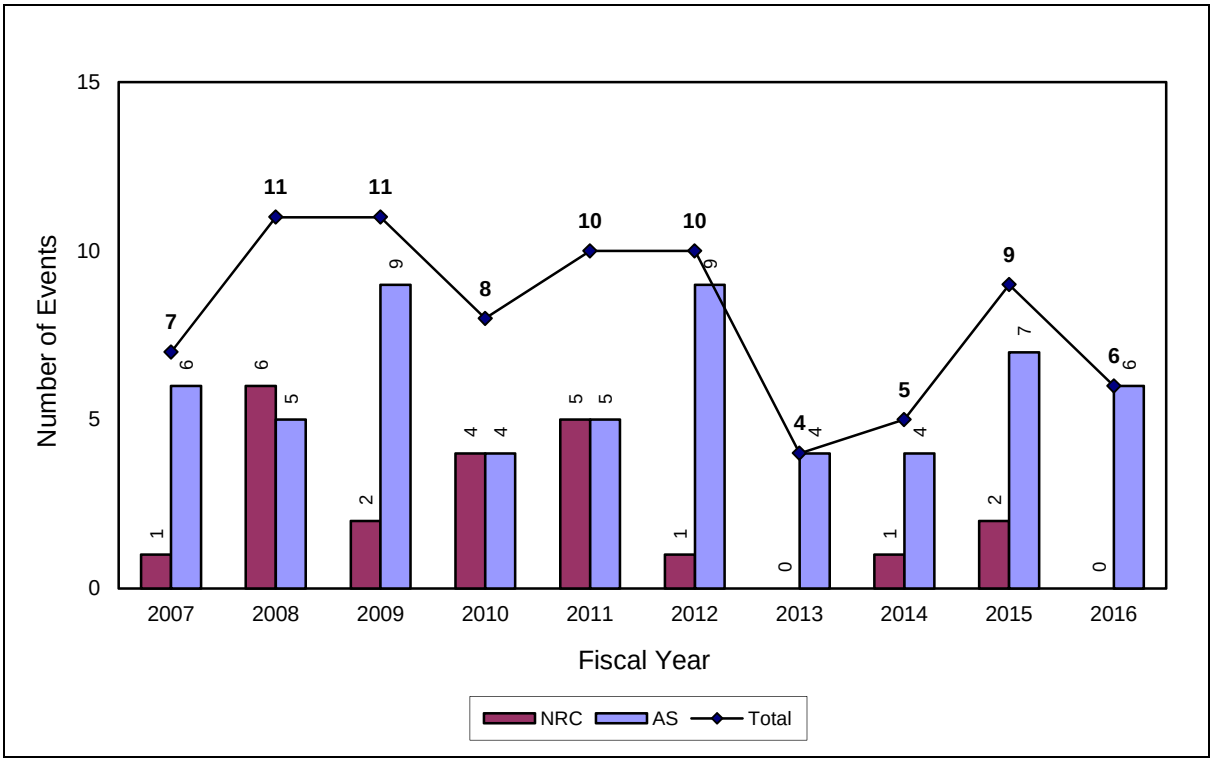

Figure 5. Release of Licensed Material or Contamination Events (81 total)

The significance of individual RLM events may be determined by the CFR reporting requirement applicable to the event. For example, an event that is required to be immediately reported is typically more significant than an event with a 30-day reporting requirement. For this report, events requiring immediate reporting are considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

Table 7 displays the number of events based on the different reporting requirement time categories. Note that each event is counted only once. If an event involved exposures that were reportable in more than one category, the event is counted in only the most restrictive category.

Table 7. RLM Events Classified by CFR Reporting Requirement

	Fiscal Year										
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Immediate	0	2	1	2	0	2	1	1	0	0	**9**
24-Hour	7	8	6	4	9	6	2	2	9	6	**59**
30-Day	0	1	4	2	1	2	1	2	0	0	**13**
Total	**7**	**11**	**11**	**8**	**10**	**10**	**4**	**5**	**9**	**6**	**81**

2.5.2 FY16 Data

Six RLM events occurred in FY16, none of which were considered significant.

Significant Events - Immediate Reporting
None

Events of Interest
Item Number 150572 - A radioactive source manufacturer reported a contamination event involving two radiation workers on 10/2/2015. A 1.11 TBq (30 Ci) Co-60 source was being manufactured within a hot cell. During the process of double encapsulating the sealed source, the welder malfunctioned. Two radiation workers within the hot cell (behind the room divider) attempted to grind off the ruined outer encapsulation. That resulted in the two workers inhaling Co-60. Nasal swipes indicated 11,743 cpm on the highest wipe. The event was contained within the hot cell, except for some footprints outside the cell, which were remediated. The workers received whole body scans on 10/7, 10/12, and 10/22/2015. Internal exposure from inhalation was calculated at 3.44 mSv (344 mrem) for one worker from an intake of 85.1 kBq (2.3 µCi), and 0.73 mSv (73 mrem) for the other worker from an intake of 15.54 kBq (0.42 µCi). The manufacturer collected bioassay samples from both workers for analysis. Monthly dosimetry badge results revealed 5.2 mSv (520 mrem) for one worker and 1.42 mSv (142 mrem) for the other. The manufacturer enacted a policy to no longer rework a ruined source during manufacturing by grinding on it; they will retire/dispose of the defective source. This event was classified as an EQP, LKS, and RLM event.

Item Number 160096 - On 2/23/2016, a recycling facility in Ohio reported that shredded scrap metal from a recycling facility in Pennsylvania set off their radiation monitor alarms. The Ohio Department of Health (ODOH) and the Pennsylvania Department of Environmental Protection (PDEP) were notified. A large orphaned Ra-226 source of unknown activity is believed to have been shredded at the Pennsylvania facility on 2/22/2016. The damaged source contaminated shredded metal that was sent to two different Ohio recycling facilities. Contaminated shredded metal, which revealed exposure rates over 4 mSv/hour (400 mrem/hour), was isolated at the Ohio facility that reported the event. A locker room, clothes, vehicles, and workers were surveyed, with no contamination identified. However, the gloves of two workers were found to be radioactively contaminated. ODOH and PDEP responded to the other sites within their respective states. Radiation surveys are being performed of employees, vehicles, and equipment. This event was classified as an EQP, LAS, LKS, and RLM event.

Item Number 160106 - A medical center reported that a radioactive contamination event occurred on 3/2/2016, with a possible personnel shallow dose exceeding limits. A medical technologist was injecting approximately 2,997 MBq (81 mCi) of Sm-153 Quadramet when he experienced a problem with the syringe/tubing connection. A blowback occurred and a small amount of Sm-153, believed to be approximately 37 to 74 MBq (1 to 2 mCi), spilled. The patient was released and sent home. The technologist was wearing gloves, washed his hands, surveyed the area, and contacted the lead technologist. Radiation Safety was not notified until 3/3/2016. Both the technologist and lead technologist were surveyed and contamination was identified on their hands and forearms. Initial

calculations indicated a skin exposure of greater than 50 cSv (rem) for the involved technologist. Smear tests were obtained throughout the department and radioactive contamination was identified on various surfaces, including the floor, chairs, and survey meters. Contamination was also identified on other technologist's hands, gloves, shoes, and clothing. Removable contamination was identified in the involved technologist's vehicle. Radiation Safety decontaminated most areas. Surfaces and rooms that were not able to be decontaminated were closed off for decay or covered with paper to prevent further spread of contamination. It is believed that the technologist attempted to clean up the area following the spill. Housekeeping may have then unknowingly spread contamination during routine cleaning. The RSO does not believe a medical event occurred. The patient returned for a scheduled scan on 3/3/2016 and the scan appeared normal. The patient did not show signs of detectable contamination on her skin. The involved technologist did not follow proper policies and procedures, which contributed to the spread of contamination. The Pennsylvania Department of Environmental Protection performed a reactive inspection. No contamination of the skin of the technologist or lead technologist was determined to have resulted in a skin exposure exceeding 50 cSv (rem). Whole body and ring badges were sent for emergency processing with results of 35 mrem DDE and 250 cSv (mrem) extremity. Urinalysis was also performed on 3/4/2016 with no detectable activity, indicating no internal uptake. Corrective actions included review and revision of nuclear medicine radiation safety policies, dose assay documentation, personal contamination surveys, and area meter surveys. Actions also included re-education of nuclear medicine staff and students of revisions.

2.5.3 Events Recently Added to NMED That Occurred Prior to FY16

One RLM event was recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. This event was not considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - Immediate Reporting
None

Events of Interest
Item Number 150289 - A medical waste company reported that biohazardous waste received from a medical center on 5/15/2015 contained I-131 therapy waste. The waste was an immediate concern, contaminating areas of the waste facility, resulting in the temporary closure of the facility. The medical center responded immediately to the waste facility, performed surveys, and confirmed that no waste facility personnel received more than minimal external exposure from the contamination. Radiation surveys identified hot spots in areas of general contamination as high as 30 mR/hour. A consultant was called and responded to the waste facility on 5/16/2015. Contaminated areas were remediated and the facility was reopened after almost 48 hours. The consultant estimated that the waste contained less than 25.9 MBq (700 μCi) of I-131. When the waste was returned to the medical center, they confirmed that the waste originated from their facility and estimated that the waste contained 62.9 MBq (1.7 mCi) of I-131. The medical center's investigation revealed that the radiation detectors placed in areas where medical waste was packaged for offsite transport were possibly disregarded by medical center or waste facility employees who moved the waste past the detectors. The detectors were found to be inoperable on the morning of 5/15/2015, but were promptly restored to service. Corrective actions included suspending waste shipments until this event was understood, retraining personnel, adding additional physical security measures, installing video equipment in the waste area, and installing cages around the radiation detection equipment to prevent the detectors from being unplugged or rendered inoperable. This event was classified as an LAS and RLM event.

2.6 Leaking Sealed Sources

2.6.1 Ten-Year Data

Figure 6 displays the annual number and trend of LKS events that occurred during the 10-year period. The trend analysis determined that the data do not represent statistically significant trends (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

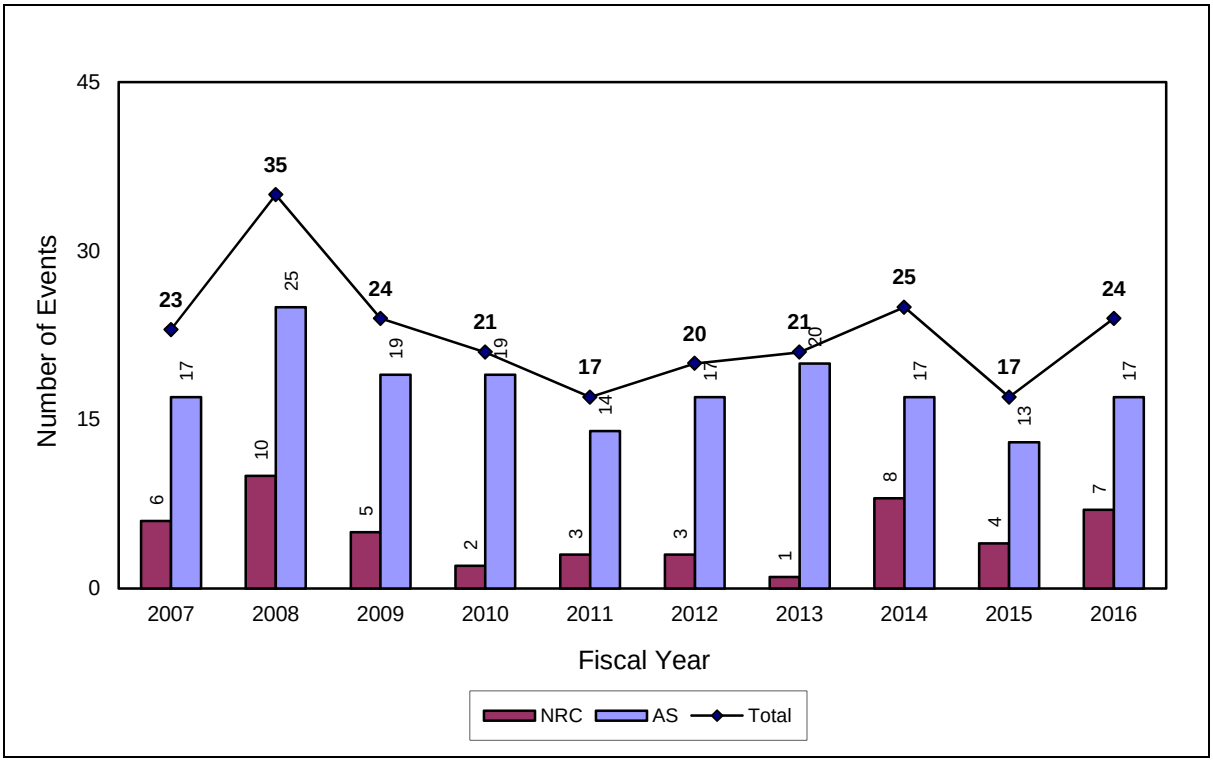

Figure 6. Leaking Sealed Source Events (227 total)

It is not possible to discern the significance of LKS events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9). There are essentially no immediate or 24-hour reporting requirements for leaking sources. The exception is 39.77(a), which is an immediate report to the NRC Regional office of a ruptured well logging source. Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.6.2 FY16 Data

Twenty-four LKS events occurred in FY16, one of which was considered significant.

Significant Events

Item Number 160266 - At least one leaking I-125 brachytherapy seed was implanted into a patient during prostate treatment on 6/17/2016. After the implant procedure was completed, the physicist surveyed the seed package and identified 180 µR/hour. The package was bagged and the RSO was contacted. The package was taken to the nuclear medicine department for surveys and wipes. The initial wipe sample revealed removable I-125 contamination of 555 kBq (15 µCi). The seed vendor requested that the package be returned for evaluation. The package originally contained 51 seeds in 15 needles; each seed contained an activity of 11.95 MBq (323 µCi). A second package of seeds was also received for the patient and a total of 1,063.64 MBq (28.747 mCi) was implanted. The medical center indicated that no

tampering of the seed package was apparent when it arrived. There were no issues during the implant procedure. The center does not believe that they caused the damage to the seed(s). The center administered a thyroid blocking agent solution to the patient and is investigating the patient's dose using blood samples and bioassays. A urine sample on 6/21/2016 was measured to be 444 Bq/ml (0.012 µCi/ml). The blood sample was measured to be 9.99 Bq/ml (0.00027 µCi/ml). The thyroid uptake measurement was 14.8 kBq (0.4 µCi) with a whole body background measurement of 2.33 kBq (0.063 µCi). The calculated thyroid dose was 1.69 cSv (rem), the bladder dose was 0.52 cSv (rem), and the whole body dose was 0.0016 cSv (rem). The patient received a routine follow-up on 7/14/2016. Another urine bioassay and thyroid uptake measurement was performed. Results revealed 17.76 Bq/ml (0.00048 µCi/ml) and 7.96 kBq (0.215 µCi), respectively. State of Wisconsin inspectors visited the center on 7/19/2016. The seed manufacturer was contacted and will notify customers of the incident. This event was classified as an EQP and LKS event.

Events of Interest

Item Number 150572 - A radioactive source manufacturer reported a contamination event involving two radiation workers on 10/2/2015. A 1.11 TBq (30 Ci) Co-60 source was being manufactured within a hot cell. During the process of double encapsulating the sealed source, the welder malfunctioned. Two radiation workers within the hot cell (behind the room divider) attempted to grind off the ruined outer encapsulation. That resulted in the two workers inhaling Co-60. Nasal swipes indicated 11,743 cpm on the highest wipe. The event was contained within the hot cell, except for some footprints outside the cell, which were remediated. The workers received whole body scans on 10/7, 10/12, and 10/22/2015. Internal exposure from inhalation was calculated at 3.44 mSv (344 mrem) for one worker from an intake of 85.1 kBq (2.3 µCi), and 0.73 mSv (73 mrem) for the other worker from an intake of 15.54 kBq (0.42 µCi). The manufacturer collected bioassay samples from both workers for analysis. Monthly dosimetry badge results revealed 5.2 mSv (520 mrem) for one worker and 1.42 mSv (142 mrem) for the other. The manufacturer enacted a policy to no longer rework a ruined source during manufacturing by grinding on it; they will retire/dispose of the defective source. This event was classified as an EQP, LKS, and RLM event.

Item Number 160096 - On 2/23/2016, a recycling facility in Ohio reported that shredded scrap metal from a recycling facility in Pennsylvania set off their radiation monitor alarms. The Ohio Department of Health (ODOH) and the Pennsylvania Department of Environmental Protection (PDEP) were notified. A large orphaned Ra-226 source of unknown activity is believed to have been shredded at the Pennsylvania facility on 2/22/2016. The damaged source contaminated shredded metal that was sent to two different Ohio recycling facilities. Contaminated shredded metal, which revealed exposure rates over 4 mSv/hour (400 mrem/hour), was isolated at the Ohio facility that reported the event. A locker room, clothes, vehicles, and workers were surveyed, with no contamination identified. However, the gloves of two workers were found to be radioactively contaminated. ODOH and PDEP responded to the other sites within their respective states. Radiation surveys are being performed of employees, vehicles, and equipment. This event was classified as an EQP, LAS, LKS, and RLM event.

2.6.3 Events Recently Added to NMED That Occurred Prior to FY16

No LKS events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events

None

Events of Interest

None

2.7 Equipment

2.7.1 Ten-Year Data

Figure 7 displays the annual number and trend of EQP events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

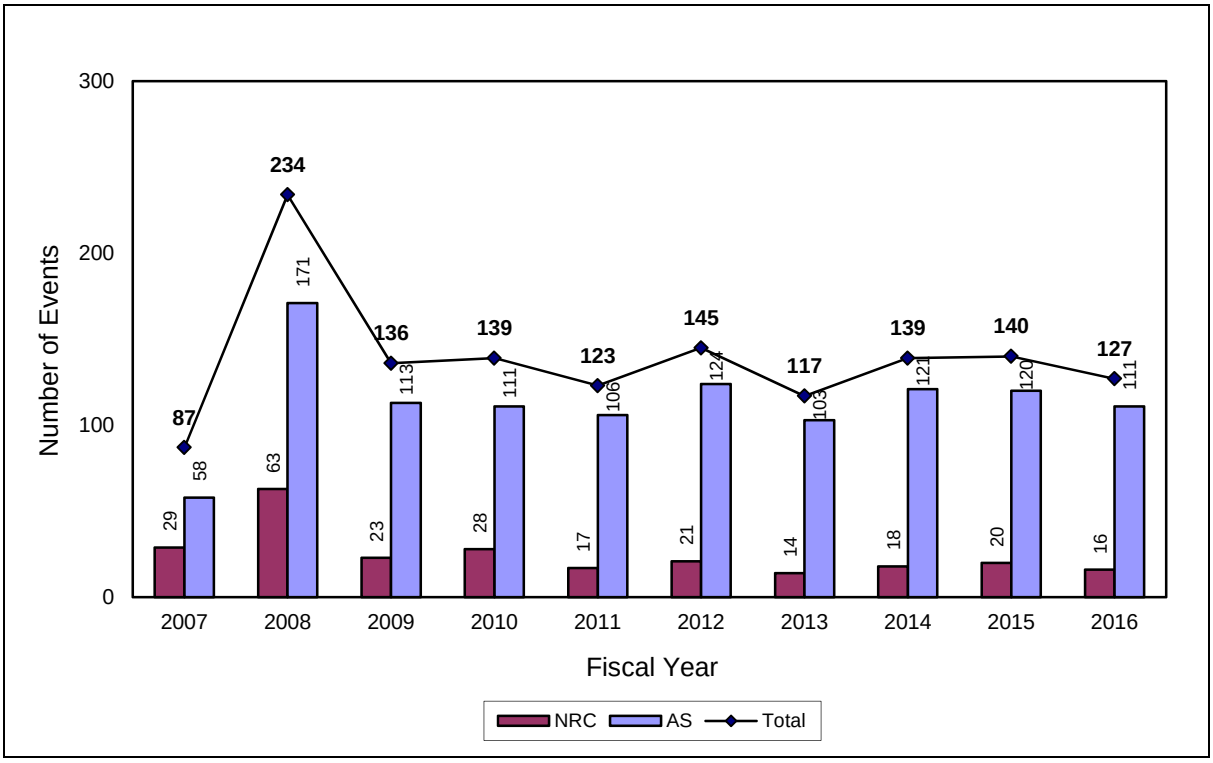

Figure 7. Equipment Events (1,387 total)

The FY08 and 09 data include 131 and 20 EQP events, respectively, which resulted from Wal-Mart's one-time review of their tritium exit sign inventory.

It is not possible to discern the significance of EQP events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9) because essentially all of the CFRs associated with EQP events require reporting within 24-hours. Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.7.2 FY16 Data

One hundred twenty-seven EQP events occurred in FY16, three of which were considered significant.

Significant Events

Item Number 150582 - A radioactive source manufacturer received a shipment from a common carrier on 10/26/2015 that contained a fixed nuclear gauge with a 27.12 GBq (733 mCi) Co-60 source. Receipt radiation surveys revealed 2 R/hour at the surface. It appears that one or more of the pull ties used to secure the shutters on the gauge broke, causing a shift in shielding. The origin of the shipment was Puerto Ordaz, Bolivar, Venezuela. It entered the U.S. through a port in Miami, Florida. It was put on a common carrier vehicle and transported to the source manufacturer in Baton Rouge, LA. The

manufacturer took possession of the gauge and moved it to a bunker on their site. The manufacturer and the Louisiana Department of Environmental Quality investigated the incident and concluded that due to the orientation of the gauge on the vehicle and the small opening in the shielding, any radiation exposure would be minimal. The company in Puerto Ordaz was bankrupt and could not pay expenses or the enforcement fine. The source manufacturer will recycle the source. This event is classified as an EQP and TRS event.

Item Number 150607 - A radiographer received a radiation overexposure during operations on 11/11/2015. He stated that he cranked out the 4,588 GBq (124 Ci) Ir-192 source, waited the appropriate time for the radiograph, and cranked the source back in. However, he failed to fully retract the source. When he retrieved the film, he noticed that his survey meter was pegged off scale. He went to his truck and checked his pocket dosimeter, which was also off scale. He then picked up the crank assembly and fully retracted the source into the radiography exposure device, which took about one quarter of a turn. He informed his supervisor that night and his monitoring badge was sent for processing. The results revealed 11.345 cSv (rem) DDE and 11.494 cSv (rem) LDE. The Texas Department of State Health Services investigated the incident and confirmed that the radiographer had not touched the source port on the exposure device while the source was unshielded. Exposure reports revealed a 2015 DDE exposure to the radiographer of 12.167 cSv (rem). Blood work was analyzed by the Radiation Emergency Assistance Center/Training Site (REAC/TS) and revealed no discernable differences compared to a normal blood sample. Corrective actions included removing involved personnel from duties involving radiation exposure, providing additional training to personnel, and providing improved supervision to personnel. As of 11/16/2015, this incident had a final International Nuclear Event Scale rating level of 2. This event was classified as an EQP and EXP event.

Item Number 160266 - At least one leaking I-125 brachytherapy seed was implanted into a patient during prostate treatment on 6/17/2016. After the implant procedure was completed, the physicist surveyed the seed package and identified 180 µR/hour. The package was bagged and the RSO was contacted. The package was taken to the nuclear medicine department for surveys and wipes. The initial wipe sample revealed removable I-125 contamination of 555 kBq (15 µCi). The seed vendor requested that the package be returned for evaluation. The package originally contained 51 seeds in 15 needles; each seed contained an activity of 11.95 MBq (323 µCi). A second package of seeds was also received for the patient and a total of 1,063.64 MBq (28.747 mCi) was implanted. The medical center indicated that no tampering of the seed package was apparent when it arrived. There were no issues during the implant procedure. The center does not believe that they caused the damage to the seed(s). The center administered a thyroid blocking agent solution to the patient and is investigating the patient's dose using blood samples and bioassays. A urine sample on 6/21/2016 was measured to be 444 Bq/ml (0.012 µCi/ml). The blood sample was measured to be 9.99 Bq/ml (0.00027 µCi/ml). The thyroid uptake measurement was 14.8 kBq (0.4 µCi) with a whole body background measurement of 2.33 kBq (0.063 µCi). The calculated thyroid dose was 1.69 cSv (rem), the bladder dose was 0.52 cSv (rem), and the whole body dose was 0.0016 cSv (rem). The patient received a routine follow-up on 7/14/2016. Another urine bioassay and thyroid uptake measurement was performed. Results revealed 17.76 Bq/ml (0.00048 µCi/ml) and 7.96 kBq (0.215 µCi), respectively. State of Wisconsin inspectors visited the center on 7/19/2016. The seed manufacturer was contacted and will notify customers of the incident. This event was classified as an EQP and LKS event.

Events of Interest

Item Number 150556 - A construction materials testing company reported that the shutter on a moisture/density gauge was stuck open. The gauge contained a 1.48 GBq (40 mCi) Am-Be source and a 0.3 GBq (8 mCi) Cs-137 source. The incident was discovered on 10/9/2015 during a Texas Department of State Health Services inspection at the company's facility. The gauge was in its transport case and the Cs-137 source was fully retracted. The company inspected the shutter and found debris around it. After the shutter area was cleaned, the shutter closed properly. The gauge had been used on 10/8/2015 by a

technician working in a field near ponds. The company does not believe any significant radiation exposure was received by the operator or any member of the public.

Item Number 150559 - A construction materials testing company reported that a moisture/density gauge, containing a 1.63 GBq (44 mCi) Am-Be source and a 0.33 GBq (9 mCi) Cs-137 source, was damaged on 10/10/2015. A technician had placed the gauge on his truck, forgot it was there, and driven away. The gauge fell from the truck and broke when it hit the ground; the sources were compromised from their cases. The technician picked up the pieces and isolated the sources in a cooler. The technician was wearing dosimetry and did not detect a change in the level of radiation. The Kansas Department of Health and Environment recommended filling the cooler with sand/dirt to aid in shielding. Johnson County HAZMAT responded to the site and performed radiation surveys, which revealed background levels. Additional personnel from the material testing company responded to the site and verified that the radiation sources were secured. Contamination swipes were taken on the container and revealed negative results. Radiation surveys confirmed background results. The damaged gauge was transported to the company's headquarters for secure storage pending return to the manufacturer. Corrective actions included providing additional training to personnel.

Item Number 150572 - A radioactive source manufacturer reported a contamination event involving two radiation workers on 10/2/2015. A 1.11 TBq (30 Ci) Co-60 source was being manufactured within a hot cell. During the process of double encapsulating the sealed source, the welder malfunctioned. Two radiation workers within the hot cell (behind the room divider) attempted to grind off the ruined outer encapsulation. That resulted in the two workers inhaling Co-60. Nasal swipes indicated 11,743 cpm on the highest wipe. The event was contained within the hot cell, except for some footprints outside the cell, which were remediated. The workers received whole body scans on 10/7, 10/12, and 10/22/2015. Internal exposure from inhalation was calculated at 3.44 mSv (344 mrem) for one worker from an intake of 85.1 kBq (2.3 μCi), and 0.73 mSv (73 mrem) for the other worker from an intake of 15.54 kBq (0.42 μCi). The manufacturer collected bioassay samples from both workers for analysis. Monthly dosimetry badge results revealed 5.2 mSv (520 mrem) for one worker and 1.42 mSv (142 mrem) for the other. The manufacturer enacted a policy to no longer rework a ruined source during manufacturing by grinding on it; they will retire/dispose of the defective source. This event was classified as an EQP, LKS, and RLM event.

Item Number 150593 - A chemical company reported finding a hairline crack in the source housing of a fixed nuclear gauge that contained a 2.22 GBq (60 mCi) Cs-137 source. The source's original activity was 3.7 GBq (100 mCi) when the gauge was installed in 1992. The crack was noticed during annual operational inspections conducted on 11/4/2015. The gauge was installed on a hopper/drum, but had not been used since locked-out on 3/21/2003. The gauge remained installed on the hopper, but was not functioning. The crack was located at the union of the gauge shielding and the mounting plate of the gauge. The exposure level was approximately 150 mR/hour. A contract company was contacted to provide service. The contractor removed the source from the gauge, packaged it, and placed it into storage pending disposal. The chemical company speculated that vibration of the hopper caused the crack.

Item Number 150609 - A specialty metals manufacturer reported that a fire occurred in an off-gas dust collector and particulate filtration system used for ventilation from a process providing oxidation of depleted uranium chips. Fire alarms sounded on 11/16/2015 and the fire suppression system engaged. The local fire department responded and reinforced the suppression system. The fire department departed two hours after the fire started. Initial indications revealed that no release of radioactive material occurred, based on visual observations and no alarms from the stack monitoring systems. Negative building pressure was maintained. Post event radiological surveys revealed that no radioactive contamination was spread outside of the building and remained localized to the event. Contaminated areas were decontaminated to below action levels. Contaminated equipment was segregated for decontamination. Air samples were pulled immediately following the incident and the highest level of

activity found was 0.8 derived air concentration (DAC) alpha at the oxide hood. No personnel exposures were identified through nasal smears and bioassay samples of involved personnel. The manufacturer will perform an engineering evaluation of the need for an additional spark arrestor and other modifications in the ventilation system. They will add a data logger to the duct work resistance temperature detectors, implement a documented ventilation system inspection process, implement a process improvement for documenting the oxide processing operation, and evaluate installing additional sprinklers.

Item Number 160002 - A construction materials testing company reported that a moisture/density gauge was run over by a bulldozer on 12/21/2015. The gauge contained a 1.85 GBq (50 mCi) Am-Be source and a 0.37 GBq (10 mCi) Cs-137 source. The Cs-137 source rod was extended and the gauge casing was damaged. The RSO responded to the site and determined that the Am-Be source had detached from the casing and the Cs-137 source was exposed. The Cs-137 source rod was not able to be returned to its shielded position. The California Health and Human Services Agency was contacted and an inspector responded to the site. The inspector determined that the Am-Be source was not damaged, but was detached from the gauge body. The Cs-137 source was also intact, but was in the extended position and the opposite end of the source rod was broken off at the top of the shield, preventing the source from being retracted into the shielded position. No radioactive contamination was identified. A small lead pig was taped to the Cs-137 source and the two sources were placed into the gauge transportation case. Radiation surveys revealed 17 mR/hour on contact with the case. Department of Transportation Exemption CA-CA-15-99 was issued and the RSO transported the sources to the company's facility for secure storage pending proper disposal. Corrective actions included implementing a policy that requires gauge operators to notify field foremen to stop all running equipment on jobsites prior to moisture/density testing. The gauge operators are to refuse testing if any equipment remains running.

Item Number 160029 - A construction materials testing company reported that a moisture/density gauge was hit and damaged by a truck at a temporary jobsite on 1/13/2016. The gauge contained a 1.48 GBq (40 mCi) Am-Be source and a 0.3 GBq (8 mCi) Cs-137 source. The Cs-137 source rod became detached from the gauge. The area was secured and a local service provider was contacted to recover the gauge. The gauge was recovered and leak tests performed on 1/14/2016 revealed negative results. The gauge was shipped to the gauge manufacturer for repair or replacement. The Pennsylvania Department of Environmental Protection performed a reactive inspection. The company stated that gauge operators now carry radios to alert nearby equipment operators when performing tests. No testing is performed until all equipment is stationary. Gauge operators will enter and exit testing locations from one access point.

Item Number 160060 - A construction materials testing company reported a complete failure of a moisture/density gauge that contained a 0.3 GBq (8 mCi) Cs-137 source. The source dropped from the rod onto the ground on 2/1/2016. The incident occurred at a construction site. The loose source was placed into a concrete container and secured at the company's facility. The gauge manufacturer sent a lead pig overnight. Radiation surveys were performed around the storage area to ensure exposure rates were below limits. The company believes that the equipment failure was attributed to the gauge being 20 years old. They returned the gauge to the gauge manufacturer for analysis and disposal. The company informed all gauge users of the event and emphasized correct procedures, retrained the involved gauge user, and reviewed their corporate safety culture for areas that need enhancement. The NRC Registry of Radioactive Sealed Sources and Devices indicates that this device also contains an Am-Be source with a maximum activity of 1.48 GBq (40 mCi).

Item Number 160085 - A paper company reported that two unused process nuclear gauges had been sent to a scrap yard. Each gauge contained a 1.85 GBq (50 mCi) Cs-137 source (assayed 1988). The incident was discovered during a source inventory. It was determined that while performing demolition at their facility, the two gauges were removed from the site. Removal of the gauges was outside the scope of the demolition work. The gauges were located on long poles that were removed from the site using a crane and sent to a nearby scrap yard. The South Carolina Division of Health and Environmental Control was contacted and sent an inspector to the scrap yard. Both gauges were recovered. The shutter on one gauge

was partially open and radiation readings revealed 50 mR/hour on contact. Wipe tests on both gauges revealed negative results. The gauges were returned to the paper company and locked in a secure location. The company will improve visibility, location, and clarity of radioactive device signage. They will also improve the process for out-of-service devices, preventative maintenance of radioactive devices, and procurement/engineering processes for demolition labor.

Item Number 160096 - On 2/23/2016, a recycling facility in Ohio reported that shredded scrap metal from a recycling facility in Pennsylvania set off their radiation monitor alarms. The Ohio Department of Health (ODOH) and the Pennsylvania Department of Environmental Protection (PDEP) were notified. A large orphaned Ra-226 source of unknown activity is believed to have been shredded at the Pennsylvania facility on 2/22/2016. The damaged source contaminated shredded metal that was sent to two different Ohio recycling facilities. Contaminated shredded metal, which revealed exposure rates over 4 mSv/hour (400 mrem/hour), was isolated at the Ohio facility that reported the event. A locker room, clothes, vehicles, and workers were surveyed, with no contamination identified. However, the gloves of two workers were found to be radioactively contaminated. ODOH and PDEP responded to the other sites within their respective states. Radiation surveys are being performed of employees, vehicles, and equipment. This event was classified as an EQP, LAS, LKS, and RLM event.

Item Number 160120 - A construction materials testing company reported that a moisture/density gauge, which contained a 1.63 GBq (44 mCi) Am-Be source and a 0.41 GBq (11 mCi) Cs-137 source, was damaged at a jobsite on 3/11/2016. The gauge housing was damaged and the source rod was bent. When staff approached the gauge, radiation readings were 5 mR/hour at five feet, indicating that the sources were not properly shielded. When staff surveyed the bottom of the gauge at the shutter, the source rod fell out from the top of the gauge. The gauge pieces were moved to survey the incident area and readings revealed background results. The source rod was placed back into the gauge housing. Radiation readings at the bottom of the gauge with the source rod in place revealed between 150 and 200 mR/hour. The reassembled gauge was placed back into its shipping container and properly braced and blocked in the company's truck. The gauge was transported directly to the gauge manufacturer's facility and will be stored pending an assessment of the damage. Radiation surveys at the scene indicated that the sources were intact and not leaking. Swipes on the source rod, gauge, and other equipment, confirmed no leakage. Corrective actions included a review of procedures, retraining of gauge operators, and a new presentation on loss of control of material and its implications.

Item Number 160127 - A medical center reported that a patient only received prostate treatment to nine of 19 prescribed interstitial catheter sites during a high dose rate (HDR) prostate treatment on 3/16/2016. The treatment involved an HDR unit and a 386.76 GBq (10.453 Ci) Ir-192 source. The incident occurred during the patient’s second fraction (the first was performed two weeks earlier without issue). The patient was prescribed 1,350 cGy (rad) to 30 cc of the prostate volume (99.75% of the prostate gland). During the third dwell position of the tenth catheter, the HDR treatment console reported error code 9 (indicating that the source had moved from the dwell position and that a reset of the console was required). While retracting the source, the console reported error code 4 (friction was detected during source in-drive). Following a reset of the treatment console, attempts to continue the treatment failed. Phone support was obtained from an HDR equipment field services company to troubleshoot the issue. Error code 117 (indicating an error while driving out the check cable) was also noted. Patient treatment was halted and the patient was sent to recovery. A field service engineer visited the site and determined that some equipment parts required replacement. The patient and the patient’s family were informed of the medical event. The medical center determined that the total prescribed treatment time was 386.6 seconds, but the actual treatment time was only 158.5 seconds. During that time, only 12.52% of the prescribed prostate treatment volume received its intended 1,350 cGy (rad). Repairs of the HDR unit were completed on 3/17/2016 and a different patient was successfully treated on 3/18/2016. The treatment of the affected patient was delayed for about two weeks. This event was classified as an EQP and MED event.

Item Number 160139 - A medical center reported that a patient only received treatment to one of 18 interstitial catheter sites during an HDR prostate treatment on 3/22/2016. The treatment involved an HDR unit and a 366.6 GBq (9.908 Ci) Ir-192 source (as of 3/11/2016). The patient was prescribed 1,350 cGy (rad) to the prostate for the second fraction. During treatment, after completion of the first catheter, the treatment console reported error code 4 (friction was detected during source in-drive) and the source was retracted. The unit was reset, but the problem persisted. Error code 117 (indicating an error while driving out the check cable) was also noted. Phone support was obtained from an HDR equipment field services company to troubleshoot the issue. It was again determined that several equipment parts required replacement. The treatment was stopped and the patient was notified. The medical center calculated that the patient received 0.16% of the prescribed dose of 1,350 cGy (rad). The patient was scheduled to receive the remainder of the prescribed dose at a later time. This event was classified as an EQP and MED event.

Item Number 160147 - During an NRC inspection of a construction materials testing company on 3/18/2016, the inspector found that the Cs-137 shutter was partially open on a moisture/density gauge. The exposure rate at the surface of shutter was 280 mR/hr. The area with the highest exposure rate was an unoccupied crawlspace beneath the gauge storage area. The handle for the source rod had been removed and was stored near the gauge. No damage to the gauge or handle was observed. The RSO was unaware that the handle had been removed, indicated that no gauges had been used since September 2012, and stated that there had been no accident or damage to the gauge. The manufacturer was contacted and confirmed that the handle is not designed to be detached by gauge users. The manufacturer instructed the RSO to reattach the handle to the source rod with tape until a specific Allen wrench could be obtained to secure the handle to the source rod. With the handle taped in place and the gauge stored in its case, the exposure rate closest to the shutter was 4 mR/hr. The facility plans to transfer all three of their gauges via the orphan source program by September 2016. According to the NRC Registry of Radioactive Sealed Sources and Devices, this gauge contains an Am-Be source with a maximum activity of 1.85 GBq (50 mCi) and a Cs-137 source with a maximum activity of 0.37 GBq (10 mCi). This event was classified as an EQP and OTH event.

Item Number 160300 - A recycling facility reported that a shipment of scrap metal set off their radiation monitor alarms on 7/11/2016. The Virginia Radioactive Material Program responded to the site to investigate the incident. A fixed nuclear gauge containing a 3.7 GBq (100 mCi) Cs-137 source was identified in the shipment. The source shutter was locked partially open, with the opening behind part of the gauge mounting. Maximum radiation levels on contact at the mounting near the shutter were 5 mR/hour, with less than 0.1 mR/hour at three feet. The gauge was placed into a drum using a mechanical hoist and the drum was placed in a secured area. Onsite tests for leakage indicated no removable contamination. The recycling facility arranged for proper disposal of the gauge. Exposure estimates indicated that no individual received more than 10 µSv (1 mrem) whole body or 50 µSv (5 mrem) extremity. The gauge manufacturer is reviewing their records to identify the gauge owner. This event was classified as an EQP and LAS event.

Item Number 160308 - A construction materials testing company (an Alabama licensee working in Kansas under reciprocity) reported that a moisture/density gauge was destroyed in a truck fire on 7/19/2016. The gauge contained a 1.48 GBq (40 mCi) Am-Be source and a 0.296 GBq (8 mCi) Cs-137 source. The truck was located in a field 20 miles south of Dodge City, Kansas. Due to high grass and extreme temperatures, the truck caught fire with the gauge in the bed of the truck. The truck and gauge were completely destroyed. The wreckage was fenced off and the senior project manager remained onsite to control the area. With no survey meter onsite, the company borrowed a meter that was not calibrated. Surveys of the wreckage revealed 0.2 mR/hr at one meter. A calibrated survey meter and a Type A overpack were sent from the company's office in Tulsa, Oklahoma. The calibrated survey meter confirmed the previous survey results. Once the gauge debris was placed in the overpack, the maximum radiation levels on the overpack were 0.2 mR/hr at one meter. Surveys of the truck wreckage found no

contamination. The overpack was transported to the company's facility in Tulsa. Corrective actions included adding fire protection equipment to all vehicles and providing additional training to personnel.

Item Number 160359 - A coal-fired power plant reported that a fixed nuclear gauge containing an 18.5 MBq (500 µCi) Ra-226 source had fallen from its mounted position. The gauge had been mounted to a coal feeder. The event was discovered during a facility walkthrough by the night shift RSO on 8/15/2016. The area around the gauge, which is not normally accessed by staff, was cordoned off. Radiation readings directly on top of the gauge revealed between 0.5 and 1 mR/hour. The gauge was not manufactured with a shutter and remained in the open beam configuration. The direct beam of radiation was shielded with available lead. Vibration from the coal feeder caused the metal mounting bracket to shear. Semiannual preventative maintenance had not identified the issue. Scaffolding is required to perform maintenance on the gauge, which makes it difficult to do more often. The NRC Registry of Radioactive Sealed Sources and Devices states that the radiation level in the direct radiation beam, 16 cm from the gauge face, is 70 µSv/hour (7 mrem/hour). The power plant updated their maintenance schedule to include more frequent checks of their gauges. The gauge was secured on a lead plate and staged in a labeled 55-gallon steel drum to be disposed of at a later date. It will remain in storage under lock and key until that date. The power plant's next inspection will include a review of the implemented changes.

Item Number 160365 - A radiography services company reported the inability to retract a 2.37 TBq (64 Ci) Ir-192 source into a radiography exposure device and the possibility of radiation overexposure to personnel. On 8/9/2016, the radiography exposure device had been placed on a ladder with the source cranked out. The exposure device then fell from the ladder. The radiographer checked his survey meter, which read 0, and proceeded to adjust the collimator. A second radiographer came to assist and noted that his detector revealed high radiation readings. The radiographers' rate meters never alarmed. The crew was unable to retract the source. The RSO responded and was able to secure the source back into the exposure device. The RSO's direct reading dosimeter received 200 mR during the retrieval process. The radiographers' and RSO's dosimeters were sent to the film badge provider for processing. Results revealed that the RSO received 451 mR DDE, the lead radiographer received 11 mR DDE, and the second radiographer received 7 mR DDE. The RSO calculated that the second radiographer received 809 mR DDE and an extremity exposure of 4.3 cSv (rem). Both radiographers failed to follow established operating and emergency procedures. The lead radiographer was fired and the second radiographer was removed from radiography assignments to receive more training. The lead radiographer's survey meter was repaired. The company will discuss the incident in annual refresher training.

Item Number 160409 - A phosphate mining company reported a potential radiation exposure incident involving a fixed nuclear moisture gauge containing an 11.1 GBq (300 mCi) Am-Be source. In June 2016, the gauge manufacturer was contacted to put the device into service. However, due in part to a problem with the vessel's dip tube, the manufacturer was unable to make the gauge operate as intended. They removed the shield plug, but did not reinstall it prior to leaving. Because the gauge was keyed to the locked position, mining company personnel assumed that the source was locked in the gauge in the shielded position (the gauge manufacturer did not communicate the need to reinstall the plug to shield the source if the gauge was detached from the vessel). On 9/27/2016, the mining company tasked a contract electrician to remove the defective dip tube from the vessel. This work was not coordinated with the RSO. The electrician detached the gauge from the vessel. A short time later, the electrician noticed a cylinder sticking several inches out of the gauge. The electrician used a wrench to partially push the cylinder back into the device, applied tape to hold it in place, and reported to his supervisor. The mining company immediately contacted the manufacturer, who determined that the gauge's source likely became exposed when the electrician detached the gauge from the vessel. The mining company then re-attached the gauge to the vessel to minimize potential exposure to the source. The company's initial exposure estimates to the electrician were 3.91 mR whole body and 10.83 mR extremity (the worst case exposure estimates were 23.87 mR whole body and 42.98 mR extremity). The manufacturer arrived onsite on 9/29/2016. NRC Region IV was also contacted and personnel responded to the site to observe and

investigate. The Region's investigation is in progress and they have stated that it appears no overexposure occurred.

2.7.3 Events Recently Added to NMED That Occurred Prior to FY16

Ten EQP events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. One of these events was considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events

Item Number 150140 - A medical center reported eight medical events involving a gamma knife unit that contained 244.2 TBq (6,600 Ci) of Co-60. Five of the events exceeded the NRC's Abnormal Occurrence criteria. The patients were being treated for acoustic neuromas and metastatic tumors in the brain. All eight patients received their prescribed doses, ranging from 1,300 to 2,400 cGy (rad), to the wrong location due to misalignment of the patient positioning system. This misalignment occurred during maintenance of the unit between 12/13/2014 and 1/1/2015 by the gamma knife unit manufacturer, which resulted in the patient positioning system being off-target by 1.87 mm. The eight patient treatments were performed between 1/7/15 and 2/12/2015. All of the patients and referring physicians were notified. The effects to the patients are still being determined. The cause of the misalignment of the patient positioning system was the failure to use the correct service procedures during maintenance. Corrective actions include the development of a new set of tests to verify patient positioning. This event was classified as an EQP and MED event.

Events of Interest

Item Number 150437 - A radioactive material shipping cask manufacturer reported that radioactive material transport package shielding for a shipping cask potentially failed to comply with 10 CFR Part 21. This is not a defect of the package, but rather an un-analyzed condition that could lead to a safety hazard. Specifically, the Safety Analysis Report did not analyze the radiation levels on the exterior of the package when a point source was located in a corner of the cask cavity. There were three casks in service by customers, one cask not in service, and casks on hold for completion of fabrication activities. As of 8/6/2015, package owners were notified in writing. The manufacturer put administrative controls and compensatory measures in place to address the situation and lessen the likelihood of a potential relocation of a source (which could reduce the effectiveness of the shielding of the package) and allow the package to be used with the intent of providing an equivalent level of safety during shipment. Actions included shoring placed between the inner container and the package cavity walls to secure and immobilize the containers in the center of the cavity, performing comprehensive radiation surveys at every location on the surface to determine the transport index, inspecting all transport equipment prior to shipment, and determining the best course of action for performing shielding analysis. To date, the package has only been used to transport Co-60. Activities used in the Safety Analysis Report were 123 TBq and 810 TBq (3,330 and 21,900 Ci) of Co-60.

Item Number 150461 - On 8/4/2015, a recycling facility notified the Alabama Office of Radiation Control that they had contaminated items that needed to be transferred to a radioactive waste broker. On 8/4 and 8/7/2015, Alabama personnel visited the facility to investigate the items. Three 55-gallon drums contained pipe contaminated with naturally occurring radioactive material; the highest reading on the outside of the drums was 1.4 mR/hr. There was also a manifold containing Th-232 with a reading of 0.75 mR/hr. The last item was a damaged and rusty gauge without a shutter. The gauge contained a Sr-90 source and read 1,500 mR/hour (beta/gamma) and 300 mR/hour (gamma) at the port opening. There were no identifying marks on the gauge and the owner was unknown. A leak test was performed. The gauge was secured and placed into storage at the recycling facility pending disposal. A radioactive waste broker picked up the gauge/source on 1/12/2016 under the orphan source program. The source was estimated to contain a Sr-90 activity of 1,850 MBq (50 mCi). This event was classified as an EQP and LAS event.

2.8 Transportation

2.8.1 Ten-Year Data

Figure 8 displays the annual number and trend of TRS events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within those annual values represent random fluctuation around the average of the data.

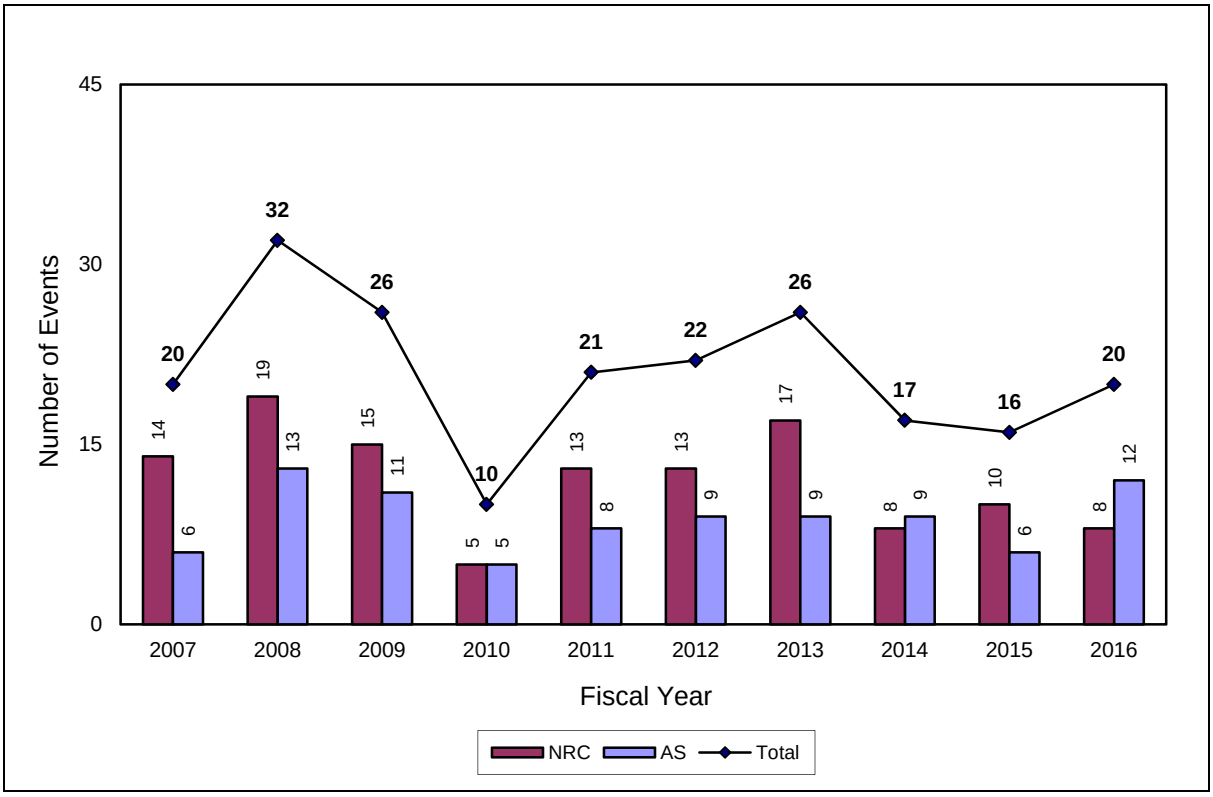

Figure 8. Transportation Events (210 total)

It is not possible to discern the significance of TRS events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9). Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.8.2 FY16 Data

Twenty TRS events occurred in FY16, two of which were considered significant.

Significant Events

Item Number 150582 - A radioactive source manufacturer received a shipment from a common carrier on 10/26/2015 that contained a fixed nuclear gauge with a 27.12 GBq (733 mCi) Co-60 source. Receipt radiation surveys revealed 2 R/hour at the surface. It appears that one or more of the pull ties used to secure the shutters on the gauge broke, causing a shift in shielding. The origin of the shipment was Puerto Ordaz, Bolivar, Venezuela. It entered the U.S. through a port in Miami, Florida. It was put on a common carrier vehicle and transported to the source manufacturer in Baton Rouge, LA. The manufacturer took possession of the gauge and moved it to a bunker on their site. The manufacturer and the Louisiana Department of Environmental Quality investigated the incident and concluded that due to the orientation of the gauge on the vehicle and the small opening in the shielding, any radiation exposure

would be minimal. The company in Puerto Ordaz was bankrupt and could not pay expenses or the enforcement fine. The source manufacturer will recycle the source. This event is classified as an EQP and TRS event.

Item Number 160176 - The Environmental Protection Agency reported that a common carrier was transporting a shipment with radiation levels that exceeded limits. The package contained a 110.26 GBq (2.98 Ci) Ir-192 HDR brachytherapy source that was being sent back to the source manufacturer from a medical center in the Philippines. The shipment consisted of a bucket on a pallet wrapped in plastic and held in place with a cinch strap. Customs and Border Patrol informed the common carrier's RSO that radiation levels were higher than expected. The RSO's survey results were not consistent with Customs' results. The exposure rate on contact with the top of the shipment was 15 cSv/hour (rem/hour). The shipping container was opened at the common carrier's facility in Houston, Texas, and the Ir-192 source was found sitting on top of its shield. The highest exposure rates were 54.2 cSv/hour (rem/hour) on contact. Both security seals were also missing from the shipping container. It was noted that the drive cable near the source was damaged. Personnel at the facility contacted 911. A hazardous material (HAZMAT) team responded to the site and evacuated the facility. The Texas Department of State Health Service contacted the HAZMAT team leader, who stated that radiation surveys at 200 feet revealed background results. HAZMAT placed the shipping bucket into a 30-gallon container. That container was filled with a dry clay material and sealed. The container was then placed inside a 55-gallon drum, which was filled with water and sealed. The source manufacturer was contacted and a representative responded. The representative identified radiation levels of 7 cSv/hour (rem/hour) on contact with the sides of the drum and 0.41 mSv/hour (41 mrem/hour) at three feet. With the lid removed from the drum, exposure rates were 15 R/hour. The recovery team's dosimetry badges were sent for processing and revealed radiation exposures of 72 and 18 mR. No other individuals were identified as receiving radiation exposure. The source manufacturer is currently storing the source. The common carrier and Customs' employees were retrained on radiation hazards and safety.

Events of Interest

Item Number 160382 - A uranium mining company shipped a leaking intermodal container of barium sulfate sludge, a byproduct of uranium ore processing bearing low levels of radioactive materials, from Wyoming to a uranium mill in Utah. The mill received the shipment on 3/29/2016 and identified a white paste-like substance on the transport container, the transport conveyance, and the highway near the mill. Surveys of the highway and roadway ranged from 5,850 to 9,360 dpm/100 cm^2 alpha and 0.04 to 0.08 mrem/hr beta/gamma. Swipes for removable alpha contamination on the asphalt roadway ranged from 383 to 492.5 dpm/100 cm^2 alpha. Surveys of the conveyance ranged from 35,100 to 58,500 dpm/100 cm^2 alpha and 5 mrem/hr beta/gamma. Swipes for removable alpha contamination ranged from 438.8 dpm/100 cm^2 on the tires to 2,551.3 dpm/100 cm^2 on the beam under the potential source of the leak. The driver stated that on 3/28/2016 he had braked hard when a deer ran in front of the truck in Colorado, but no leakage was noted when he stopped later for gas in Wyoming. The driver noticed the leak when he arrived at the mill at 11:30 p.m. on 3/28/2016. Due to rain and snow storm at the time of the shipment, any additional road contamination was washed away, making it impossible to determine where the leak began. The area on the highway and the roadway leading to the mill was washed and contaminated soil (5 to 6 cubic yards) was removed. The conveyance was moved to another location for decontamination and release. On 4/1/2016, the mining company sent a team to survey the highway along the route; no readings above background were noted. This was the second incident of this type involving this material; the previous incident occurred on or about August 19-20, 2015. The mining company suspended barium sulfate sludge shipments pending completion of corrective actions. The NRC conducted an inspection on June 20-23, 2016. Corrective actions included changing the containers used to transport sludge, further dewatering of the material prior to shipment, and changing the absorbent material.

2.8.3 Events Recently Added to NMED That Occurred Prior to FY16

Two TRS events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. Neither of these events was considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events
None

Events of Interest
None

2.9 Other

2.9.1 Ten-Year Data

Figure 10 displays the annual number of OTH events that occurred during the 10-year period. Because OTH events do not fit a defined criterion that ensures consistency within the data, trending analysis is not performed on this data.

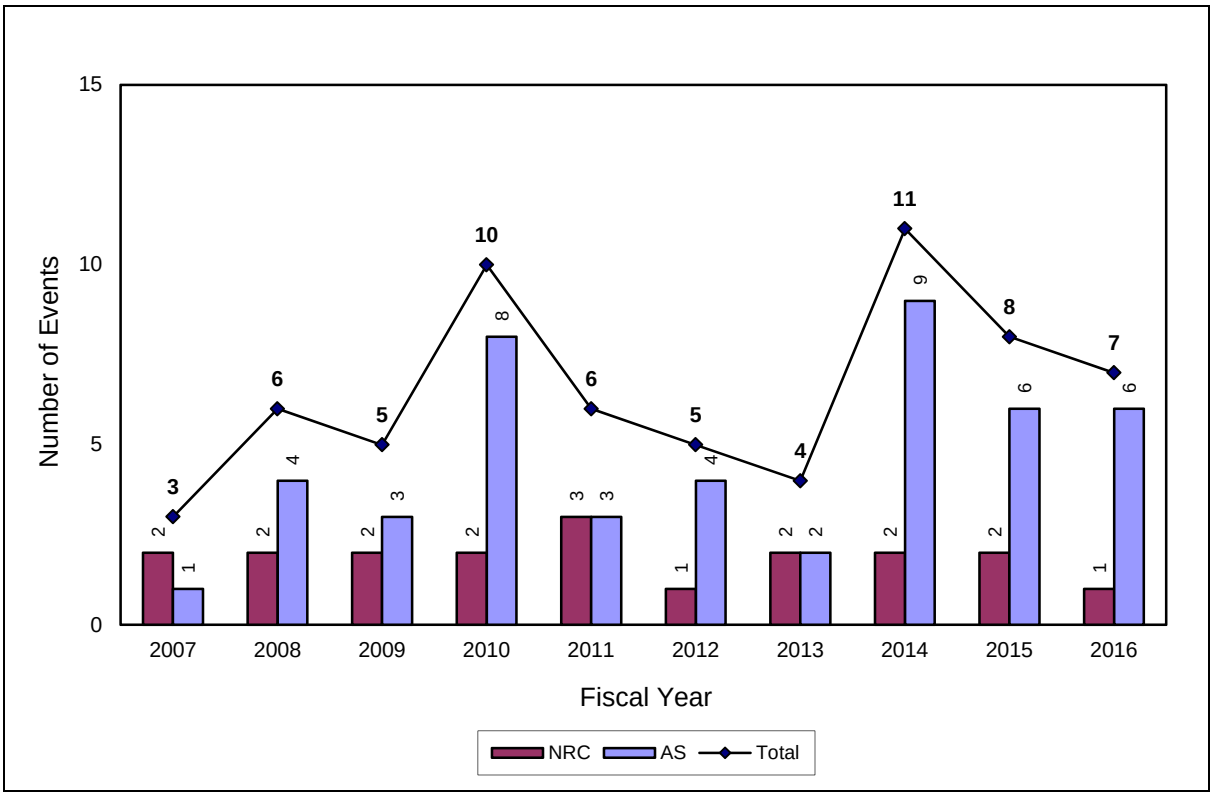

Figure 9. Other Events (63 total)

It is not possible to discern the significance of OTH events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9). Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.9.2 FY16 Data

Seven OTH events occurred in FY16, one of which was considered significant.

Significant Events

Item Number 160366 - A pregnant patient received a thyroid ablation treatment on 7/13/2016. The prescribed dosage was 2.78 GBq (75 mCi) of I-131 and the patient received 2.89 GBq (78 mCi). Subsequently, the patient became aware that she was pregnant at the time of the procedure and informed the medical center on 8/16/2016. Fetal gestation at the time of the treatment was estimated to be nine days post conception. The RSO estimated an exposure to the embryo/fetus of approximately 20 cGy (rad). The patient was administered a pregnancy test prior to treatment and the results were negative. The medical center stated that the incident was a result of patient non-compliance because she was instructed not to have sexual contact prior to the administration. This event was classified as a potential Abnormal Occurrence.

Events of Interest

Item Number 160022 - A radiography services company reported an unauthorized entry and attempted theft of seven radiography exposure devices at 3:16 a.m. on 1/11/2015. Each device contained an Ir-192 source with activities of 2035, 999, 1406, 2590, 407, 592, and 740 GBq (56, 27, 38, 70, 11, 16, and 20 Ci), respectively. A security video revealed a thief breaking into the locked storage vault. The alarm sounded and the thief left the facility without taking any radioactive material. Local law enforcement responded within six to seven minutes of the alarm. A Louisiana Department of Environmental Quality inspector visited the site on 1/12/2016 to investigate the incident. The company is upgrading their security system due to the incident.

Item Number 160121 - A chemical company reported a radiation exposure rate that exceeded (20 µSv) 2 mrem in any hour in an unrestricted area. The incident was identified by a consultant on 2/23/2016. The company was calibrating a fixed level gauge, which contained a 111 GBq (3 Ci) Cs-137 source, following a procedure not previously used. During the calibration, an individual monitoring exposure rates in the area noted a reading of 150 µSv/hour (15 mrem/hour) where he was standing. The individual also identified an exposure rate of 120 µSv/hour (12 mrem/hour) where two non-radiation workers were working. Those workers had been in the area for 45 minutes. The company calculated the exposure received by the two workers to be 100 µSv (10 mrem). A follow-up detailed reported confirmed that the workers received up to 98 µSv (9.8 mrem). The Texas Department of State Health Services investigated the incident. It was determined that the calibration technicians followed procedures, but the product vessel the gauge was mounted to was empty, instead of full. When the product vessel is full, it provides shielding for the gauge source. A new procedure is being written to prevent recurrence.

Item Number 160147 - During an NRC inspection of a construction materials testing company on 3/18/2016, the inspector found that the Cs-137 shutter was partially open on a moisture/density gauge. The exposure rate at the surface of shutter was 280 mR/hr. The area with the highest exposure rate was an unoccupied crawlspace beneath the gauge storage area. The handle for the source rod had been removed and was stored near the gauge. No damage to the gauge or handle was observed. The RSO was unaware that the handle had been removed, indicated that no gauges had been used since September 2012, and stated that there had been no accident or damage to the gauge. The manufacturer was contacted and confirmed that the handle is not designed to be detached by gauge users. The manufacturer instructed the RSO to reattach the handle to the source rod with tape until a specific Allen wrench could be obtained to secure the handle to the source rod. With the handle taped in place and the gauge stored in its case, the exposure rate closest to the shutter was 4 mR/hr. The facility plans to transfer all three of their gauges via the orphan source program by September 2016. According to the NRC Registry of Radioactive Sealed Sources and Devices, this gauge contains an Am-Be source with a maximum activity of 1.85 GBq (50 mCi) and a Cs-137 source with a maximum activity of 0.37 GBq (10 mCi). This event was classified as an EQP and OTH event.

Item Number 160297 - A chemical company reported that 22 contractor employees were exposed to levels of radiation that exceeded the 20 µSv (2 mrem) in any hour limit. The incident occurred during an outage on a small vessel on 6/5 and 6/6/2016. The vessel had a fixed nuclear gauge installed on its side that contained two 1.85 GBq (50 mCi) Cs-137 sources. The employees were building scaffolding, stripping insulation, and removing pipe in the area. On 6/6/2016, the company discovered that the sources had not been returned to their shielded positions. The company and the contractor conducted exposure rate studies to identify that 22 individuals exceeded the 20 µSv (2 mrem) in any hour limit. However, none of those individuals exceeded a total exposure of 1 mSv (100 mrem). The company changed their procedures for working around nuclear gauges and provided additional training to personnel.

Item Number 160465 - A radiography services company reported that a suspicious black pickup truck was observed driving in front of their facility holding a cell phone out of the driver's side window. The individual appeared to be taking video of the facility. The local police department was contacted,

obtained statements, and reviewed the surveillance tape. The Pennsylvania Department of Environmental Protection also performed a reactive inspection, but found no evidence of activity related to possible theft, sabotage, or diversion of Category 1 or 2 quantities of radioactive material. The police also gathered a video surveillance from another business on the street. Neither video provided any identities or any proof of wrongdoing.

2.9.3 Events Recently Added to NMED That Occurred Prior to FY16

Two OTH events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. Neither of these events was considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events
None

Events of Interest
Item Number 160083 - A radiologically contaminated material recycling company reported an exposure rate of 11 mR/hour at their fence line on 4/18/2014. High exposure rate material had been mistakenly moved to an exterior wall. Upon discovery, the material was immediately moved to a shielded area. A stop-work order was issued and all future shipments of radioactive filters for shredding were cancelled. The dosimeters along the fence line were sent for emergency processing.

Item Number 160084 - A radiologically contaminated material recycling company reported that one of their fencing dosimeters revealed a result of 7.53 mSv/year (753 mrem/year) for 2013. The Tennessee Division of Radiological Health notified the company on 2/7/2014 that their co-located dosimeter revealed results of 7.51 mSv/year (751 mrem/year). The location of the dosimeters was adjacent to a radioactive filter shredding operation. Corrective actions included imposing administrative limits on their weekly fence line surveys to trigger additional monitoring. In addition, administrative exposure limits were set on pre-filters, secondary filters, and high efficiency filters.

Appendix A

Event Type Descriptions and Criteria

Appendix A
Event Type Descriptions and Criteria

The NMED events covered by this report are divided into the following categories based on the event reporting requirements defined in 10 CFR. Note that the tables in this appendix do not contain the full text of the applicable CFRs.

Lost/Abandoned/Stolen Material (LAS)

The LAS event category includes those events where licensed radioactive material is lost or found, abandoned or discovered, and stolen or recovered. The radioactive material involved can be sealed or unsealed material, specifically or generally licensed, exempt or non-exempt quantities, involve a licensee or a non-licensee, and can be found anywhere.

NMED LAS reportable events are those that meet the reporting requirements of 10 CFR Part 20.2201. Events that do not meet the 20.2201 reporting requirement thresholds are captured as not-reportable LAS events. Additionally, LAS events involving non-Atomic Energy Act material are entered into NMED as not-reportable events.

All reportable LAS events will be coded as one of the following reporting requirements. For events involving more than one source, the decision of 10 × or 1,000 × the 10 CFR Part 20 Appendix C quantity is based on the aggregate quantity of licensed material.

Table A-1. Primary LAS Reporting Requirements

Primary LAS Reporting Requirements	Reporting Requirement Summary
20.2201(a)(1)(i)	Aggregate activity ≥ 1,000 × 10 CFR Part 20 Appendix C quantity
20.2201(a)(1)(ii)	Aggregate activity > 10 and < 1,000 × 10 CFR Part 20 Appendix C quantity
39.77(d)	Irretrievable well logging source

The following additional (secondary) CFRs will be added as applicable.

Table A-2. Secondary LAS Reporting Requirements

Secondary LAS Reporting Requirements	Reporting Requirement Summary
30.55(c)	Theft/diversion of 10 Ci (or 100 Ci per year) of H 3 (not generally licensed).
37.57(a)	Unauthorized entry resulted in actual or attempted theft, sabotage, or diversion of a category 1 or category 2 quantity of material.
37.57(b)	Suspicious activity related to possible theft, sabotage, or diversion of a category 1 or category 2 quantity of material
37.81(a)	A shipment of category 1 quantities of material is lost or missing.
37.81(b)	A shipment of category 2 quantities of material is lost or missing.
37.81(c)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 1 quantities of material.
37.81(d)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 2 quantities of material.
37.81(e)	Recovery of any lost or missing shipment of category 1 quantities of material.
37.81(f)	Recovery of any lost or missing shipment of category 2 quantities of material.
39.77(b)	Loss/theft of well logging sources.

40.64(c)(1)	Theft/diversion of 15 lb (or 150 lb per year) of source material (uranium or thorium).
73.71(a)(1)	Lost shipment of any SNM.
73.App G(I)(a)(1)	Actual or attempted theft or unlawful diversion of SNM.
74.11(a)	Loss, theft or unlawful diversion (actual or attempted) of SNM or the unauthorized production of enriched uranium.
76.120(a)(2)	Loss, other than normal operating loss, of special nuclear material.
76.120(a)(3)	Actual or attempted theft or unlawful diversion of special nuclear material.
150.16(b)(1)	Actual or attempted theft or unlawful diversion of SNM.
150.17(c)(1)	Attempted theft or unlawful diversion of more than 6.8 kg (15 lb) of Uranium or Thorium at any one time or more than 68 kg (150 lb) in any one calendar year.
150.19	Theft/diversion of 10 Ci (or 100 Ci per year) of H-3 (not generally licensed). Note: This requirement is just like 30.55(c), but applies to Agreement States and offshore waters.

Medical (MED)

MED events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-3. MED Reporting Requirements

MED Reporting Requirements	Reporting Requirement Summary
35.3045(a)(1)(i)	Total dose delivered that differs from the prescribed dose by 20% or more; and differs from the prescribed dose by more than 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(1)(ii)	Total dosage delivered differs from prescribed by 20% or more or falls outside the prescribed range; and results in a dose that differs from prescribed by more than 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(1)(iii)	Fractionated dose delivered that differs from the prescribed dose for a single fraction by 50% or more; and differs from the prescribed dose by more than 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(2)(i)	Administration of a wrong radioactive drug containing byproduct material that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(2)(ii)	Administration of a radioactive drug containing byproduct material by the wrong route of administration that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(2)(iii)	Administration of a dose or dosage to the wrong individual or human research subject that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(2)(iv)	Administration of a dose or dosage delivered by the wrong mode of treatment that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(2)(v)	Leaking sealed source that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(3)	Dose to the skin, organ, or tissue, other than the treatment site, that exceeds the prescribed dose by 0.5 Sv (50 rem) and 50% or more (excluding permanently implanted seeds that migrated from the treatment site).
35.3045(b)	Event resulting from patient intervention in which the administration of byproduct material or radiation from byproduct material results in unintended permanent functional damage to an organ or a physiological system, as determined by a physician.

Events are not considered MED events if they involve:

- Only a linear accelerator,
- Doses administered in accordance with a written directive (even if the directive is in error), or
- Patient intervention.

Events are considered MED events if, for example, a linear accelerator is used for therapy by mistake instead of a teletherapy unit or a teletherapy unit instead of a linear accelerator.

For purposes of determining whether to categorize an event as MED or EXP, MED events occur to patients only (i.e., those being administered a medical procedure). For example, if a patient receives too much dose during a procedure, the event would be categorized as MED rather than EXP. However, radiation exposure received from a cause other than the patient's medical procedure may be categorized as EXP.

Radiation Overexposure (EXP)

EXP events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-4. EXP Reporting Requirements

EXP Reporting Requirements	Reporting Requirement Summary
20.2202(a)(1)(i)	An individual received a total effective dose equivalent of 25 rem (0.25 Sv) or more.
20.2202(a)(1)(ii)	An individual received a lens dose equivalent of 75 rem (0.75 Sv) or more.
20.2202(a)(1)(iii)	An individual received a shallow-dose equivalent to the skin or extremities of 250 rad (2.5 Gy) or more.
20.2202(b)(1)(i)	Loss of control of material causing or threatening to cause an individual to receive a total effective dose equivalent exceeding 5 rem (0.05 Sv) in a period of 24 hours.
20.2202(b)(1)(ii)	Loss of control of material causing or threatening to cause an individual to receive an eye dose equivalent exceeding 15 rem (0.15 Sv) in a period of 24 hours.
20.2202(b)(1)(iii)	Loss of control of material causing or threatening to cause an individual to receive a shallow-dose equivalent to the skin or extremities exceeding 50 rem (0.5 Sv) in a period of 24 hours.
20.2203(a)(2)(i)	Doses in excess of the occupational dose limits for adults in 20.1201.
20.2203(a)(2)(ii)	Doses in excess of the occupational dose limits for a minor in 20.1207.
20.2203(a)(2)(iii)	Doses in excess of the limits for an embryo/fetus of a declared pregnant woman in 20.1208.
20.2203(a)(2)(iv)	Doses in excess of the limits for an individual member of the public in 20.1301.
20.2203(a)(2)(v)	Doses in excess of any applicable limit in the license.

The EXP event category includes all regulatory overexposures of radiation workers or exposures of members of the public to radiation. The overexposure can be external or internal and can be whole body, extremity, skin, lens of the eye, or internal dose. When the overexposure involves multiple individuals or an individual with multiple overexposure types (such as whole body and extremity), the different types of overexposures are entered separately. Note that dosimeters record exposure if improperly stored near a radiation source and, depending on the type of dosimeter, may react as though they are in a radiation field when exposed to heat or humidity. It is NRC policy to classify only those events that positively involve a personnel overexposure, and not just a dosimeter exposure, as reportable EXP events. For example, either the licensee does not contest the personnel overexposure, or in cases where the licensee does contest the overexposure, the State or NRC determines the event to be personnel overexposure.

EXP limits do not apply to patients receiving medical procedures.

Release of Licensed Material or Contamination (RLM)

RLM events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-5. RLM Reporting Requirements

RLM Reporting Requirements	Reporting Requirement Summary
20.2202(a)(2)	Release of radioactive material, inside or outside of a restricted area, so that had an individual been present for 24 hours, the individual could have received an intake 5 times the ALI.
20.2202(b)(2)	Release of material, inside or outside of a restricted area, so that, had an individual been present for 24 hours, the individual could have received an intake in excess of 1 ALI.
20.2203(a)(2)(vi)	Doses in excess of the ALARA constraints for air emissions established under 20.1101(d).
20.2203(a)(3)(i)	Radiation or concentrations of radioactive material in a restricted area in excess of any applicable limit in the license.
20.2203(a)(3)(ii)	Radiation or concentrations of radioactive material in an unrestricted area in excess of 10 times any applicable limit set forth in Part 20 or in the license.
20.2203(a)(4)	Levels of radiation or releases of radioactive material in excess of the standards in 40 CFR Part 190, or of license conditions related to those standards.
30.50(a) 40.60(a) 70.50(a) 76.120(b)	Event that prevents immediate protective actions necessary to avoid exposures to radiation or radioactive materials that could exceed regulatory limits or releases of material that could exceed regulatory limits.
30.50(b)(1) 40.60(b)(1) 70.50(b)(1) 76.120(c)(1)	Unplanned contamination event that requires access to be restricted for > 24 hours, involves > 5 times the lowest ALI, and has access restricted for a reason other than to allow isotopes with a half-life of < 24 hours to decay.
30.50(b)(3) 40.60(b)(3) 70.50(b)(3) 76.120(c)(3)	Event that requires unplanned medical treatment at a medical facility of an individual with spreadable radioactive contamination on the individual's clothing or body.
50.72(b)(3)(xii) 72.75(c)(3)	Event requiring the transport of a radioactively contaminated person to an offsite medical facility for treatment.

The RLM event category includes two types of events. The first type is a radioactive release to air or water exceeding the 10 CFR Part 20 Appendix B annual limit on intake (ALI). The second type of RLM event involves contamination events such as a radioactive spill outside of work areas, removable contamination found on equipment, or material tracked around a laboratory such that additional radiological control measures had to be implemented. This category does not include spills inside of laboratory hoods, radiopharmaceutical dose preparation areas, or hot cells where radioactive work routinely requires cleanup or changing of absorbent paper after the performance of a task. Should there be multiple release types (e.g., surface, air, water, or person) or areas of contamination associated with the release, this information is entered individually.

Leaking Sealed Source (LKS)

LKS events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-6. LKS Reporting Requirements

LKS Reporting Requirements	Type of Source
31.5(c)(5)	Generally licensed
34.27(d)	Radiography
35.67(e)	Medical
39.35(d)(1)	Well logging (leaking)
39.77(a)	Well logging (ruptured)
30.50(b)(2)	All other sources

The NRC requires that most sealed sources be periodically leak tested to verify that the material is still sealed and that the source is still considered safe to use without contamination controls, including protective clothing or gloves. Sources are generally exempt from leak testing under the following conditions [see 10 CFR Part 31.5(c)(2), 34.27(c), 35.67(f), and 39.35(e)]:

- Sources containing only gaseous radioactive material (like H-3, Kr-85, etc.),
- Sources containing licensed material with a half-life of 30 days or less,
- Sources containing <= 100 μCi of other beta and/or gamma emitting material,
- Sources containing <= 10 μCi of alpha emitting material,
- Sources held in storage in the original shipping container prior to initial installation,
- Seeds of Ir-192 encased in nylon ribbon, or
- Sources in storage and not in use (must be leak tested prior to use or transfer).

A source is considered leaking if a leak test can detect greater than 0.005 μCi of removable radioactive material. The leaking source is then removed from service, disposed of or returned to the manufacturer for repair, and a report is sent to the NRC or Agreement State with the details of the leaking source.

For regulatory reporting purposes, a leaking source is generally considered a failed device under 10 CFR Part 30. Therefore, in most cases an LKS event is also coded as an EQP event. An exception is the Ni-63 foil source, which is coded as only an LKS event.

Equipment (EQP)

EQP events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-7. EQP Reporting Requirements

EQP Reporting Requirements	Reporting Requirement Summary
21.21(d)(1)(i)	A failure to comply or a defect affecting the construction or operation of a facility or an activity that is subject to licensing requirements.
21.21(d)(1)(ii)	A failure to comply or a defect affecting a basic component that is supplied for a facility or an activity that is subject to licensing requirements.
30.50(a) 40.60(a) 70.50(a) 76.120(b)	Event that prevents immediate protective actions necessary to avoid exposures to radiation or radioactive materials that could exceed regulatory limits or releases of material that could exceed regulatory limits.
30.50(b)(2) 40.60(b)(2) 70.50(b)(2) 72.75(d)(1) 76.120(c)(2)	Equipment is disabled or fails to function as designed.
30.50(b)(4) 40.60(b)(4) 70.50(b)(4) 76.120(c)(4)	Unplanned fire or explosion that damages any licensed material or any device, container, or equipment containing licensed material.
31.5(c)(5)	Actual or indicated failure to shielding, the on-off mechanism or indicator, or upon the detection 0.005 uCi or more of removable radioactive material.
34.101(a)(1)	Unintentional disconnection of the radiographic source assembly from the control cable.
34.101(a)(2)	Inability to retract and secure the radiographic source assembly to its fully shielded position.
34.101(a)(3)	Failure of any radiographic component (critical to the safe operation of the device) to properly perform its intended function.
36.83(a)(1)	An irradiator source stuck in an unshielded position.
36.83(a)(2)	Fire or explosion in an irradiator radiation room.
36.83(a)(3)	Damage to the irradiator source racks.
36.83(a)(4)	Failure of the irradiator cable or drive mechanism used to move the source racks.
36.83(a)(5)	Inoperability of the irradiator access control system.
36.83(a)(6)	Detection of irradiator source by the product exit monitor.
36.83(a)(7)	Detection of irradiator radioactive contamination attributable to licensed radioactive material.
36.83(a)(8)	Structural damage to the irradiator pool liner or walls.
36.83(a)(9)	Abnormal water loss or leakage from the irradiator source storage pool.
36.83(a)(10)	Irradiator pool water conductivity exceeding 100 microsiemens per centimeter.
39.77(a)	Ruptured well logging sealed source.
72.75(c)(1)	Defect in any spent fuel, HLW, or reactor-related GTCC waste storage structure, system, or component that is important to safety.
72.75(c)(2)	Significant reduction in the effectiveness of any spent fuel, HLW, or reactor-related GTCC waste storage confinement system during use.
72.242(d)	Design or fabrication deficiency for any spent fuel storage cask delivered to a licensee which affects the ability of components important to safety to perform their safety function.

The EQP event category includes all types of radiological equipment problems, including generally licensed device problems covered in 10 CFR Part 31; radiography equipment problems covered in 10 CFR Part 34; irradiator problems covered in 10 CFR Part 36; well logging problems covered in 10 CFR Part 39, and other types of equipment covered in 10 CFR Part 30, 40, 70, and 76. EQP events are defined as the failure of, or a defect in, any piece of equipment that either contains licensed radioactive materials as an integral part, or whose function is to interact with such materials.

Transportation (TRS)

TRS events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-8. TRS Reporting Requirements

TRS Reporting Requirements	Reporting Requirement Summary
20.1906(d)(1)	Transported package exceeds removable surface contamination limits.
20.1906(d)(1)	Transported package exceeds external radiation limits.
71.5	Transportation of licensed material.
71.95(a)(1)	Significant reduction in the effectiveness of any NRC-approved Type B or Type AF packaging during use.
71.95(a)(2)	Defects with safety significance in any NRC-approved Type B or fissile material packaging, after first use.
71.95(a)(3)	Conditions of approval in the Certificate of Compliance were not observed in making a shipment.
71.95(b)	Conditions in the Certificate of Compliance were not followed during a shipment.

Other (OTH)

The OTH event category includes the following types of events:

1. Doses to an embryo/fetus or nursing child reportable per 10 CFR Part 35.3047. Note that these events are not MED events (reportable per 10 CFR Part 35.3045).
2. Dose in an unrestricted area in excess of 2 mR/hr, but no individual received a dose in excess of limits (if a dose in excess of limits is received, the event is an EXP event).
3. 10 CFR 37 events that do not result in the actual theft, sabotage, or diversion of Category 1 or 2 quantities of radioactive material. Otherwise, the event is as an LAS event.
4. Reportable events that do not specifically fit into one of the previous event types.

For items 1-3 above, OTH events are determined and coded per the 10 CFR reporting requirements listed below. Due to the nature of item 4 above, other reporting requirements may also be used.

Table A-9. OTH Reporting Requirements

OTH Reporting Requirements	Reporting Requirement Summary
20.2203(a)(2)(iv)	Dose in an unrestricted area in excess of 2 mR/hr, but no dose received in excess of limits.
35.3047(a)	Dose to an embryo/fetus greater than 50 mSv (5 rem) DE from administration of byproduct material or radiation from byproduct material to a pregnant individual unless specifically approved, in advance, by the authorized user.
35.3047(b)(1)	Dose to a nursing child greater than 50 mSv (5 rem) TEDE resulting from an administration of byproduct material to a breast-feeding individual.
35.3047(b)(2)	Dose to a nursing child resulting in unintended permanent functional damage to an organ or physiological system, as determined by a physician, resulting from an administration of byproduct material to a breast-feeding individual.
37.57(a)	Unauthorized entry resulted in actual or attempted theft, sabotage, or diversion of a category 1 or category 2 quantity of material.
37.57(b)	Suspicious activity related to possible theft, sabotage, or diversion of a category 1 or category 2 quantity of material
37.81(c)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 1 quantities of material.
37.81(d)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 2 quantities of material.

Appendix B

Statistical Trending Methodology

Appendix B
Statistical Trending Methodology

General

The following is a general discussion of statistical trending techniques.

A common approach to the statistical analysis of trend is based on regression methods. In particular, it is often the case that a relationship exists between the values assumed by a pair of variables. For example, if x is time (in years), and y is the rate of events per year, then we could use regression methods to study whether there is a relationship between time and event rate.

Regardless of the application, it is standard practice to refer to x as the independent variable and y as the dependent variable. Another common term for the dependent variable is "response variable," and the terms covariant and explanatory variable are sometimes used for the independent variable. Also, it is typical with regression modeling that the independent variable can be measured with little or no error, but the dependent variable involves a random error. Consequently, even if there is a deterministic functional relationship between the two variables, when data pairs (x_1, y_1), (x_2, y_2),..., (x_n, y_n) are plotted, the points will not coincide exactly with the function, but instead will tend to be scattered. Such a plot is called a scatter diagram, and shows the variation in the data. The plots in this report are bar charts containing the same information.

Fitting a Straight Line to Data

Consider a linear function

$$f(x) = \alpha + \beta x \tag{B-1}$$

where α and β are unknown parameters. A common model is that y is the sum of a linear function of the form (1) and a random error term, e. Standard results on estimation and inference about the parameters of the model assume that e is a normally distributed random variable with mean 0 and constant (but unknown) variance, σ^2. These assumptions mean that:

- Each yi is an observed value of a random quantity that is normally distributed [with mean f(xi)], and
- All the observations yi are of variables with a common variance, σ2.

The y_i are also assumed to be observations of random quantities that are independent of each other.

Under these conditions, the usual approach to estimating the unknown parameters α and β is the method of least squares (LS). In this method, α and β are selected so that the sum of the squares of the vertical distances between the data points and the fitted line is as small as possible. The LS method leads to the estimates

$$\hat{\beta} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})y_i}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \text{ and} \tag{B-2}$$

$$\hat{\alpha} = \bar{y} - \hat{\beta}\bar{x}\,, \tag{B-3}$$

where $\bar{x}$ and $\bar{y}$ are arithmetic averages. The estimated LS regression line is then

$$\hat{y} = \hat{\alpha} - \hat{\beta}x\,, \tag{B-4}$$

and an estimate of σ is

$$s = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{n-2}} \,. \tag{B-5}$$

Testing for Trend

A trend exists whenever the true slope, β, is not zero. We start the analysis with the idea that β is zero, and then ask whether the data tell us otherwise. Two quantities computed from the data are used in this assessment. The first, the *error sum of squares* (SSE), appears in the numerator of s. It is defined as

$$SSE = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \,. \tag{B-6}$$

This quantity is the number that is minimized in order to find the estimates of α and β. The differences being squared in SSE represent random variations that remain after the linear fitting process. The second quantity is the *regression sum of squares* (SSR), defined by the following equation

$$SSR = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 \,. \tag{B-7}$$

Note that SSR looks at deviations between the fitted line and the default notion that the data are constant and have no slope.

One can show by algebra that

$$SSE + SSR = SST \,, \tag{B-8}$$

where the *total sum of the squares* (SST), is defined as

$$SST = \sum_{i=1}^{n} (y_i - \bar{y})^2 \,. \tag{B-9}$$

SST measures the overall variation in the data. It is the numerator that would be used to estimate the variance in a sample from a normally-distributed random variable, where all the data in the sample have the same distribution (and thus no trend). This variance measures "random variation" in such a sample.

In the framework of the linear function (1), the regression's effectiveness is measured by the *SSR* term defined above. When it is small, the fitted curve will not differ very much from the horizontal line $y = \bar{y}$. *SSE* will be approximately equal to *SST*, and, from the data, both *SSE* and *SST* will be estimates of mere random variation. In this case, the data does not provide evidence that β is different from zero.

On the other hand, if the y values tend to vary linearly with respect to the independent variable, x, then some of the variation in the y values can be attributed to this dependence on x. Since *SSR* assesses the difference between the least squares predictions of the y values and the arithmetic mean, $\bar{y}$, it is a measure of the variation which is "explained" by the linear relationship. When the slope of the fitted line is large, more of these differences will tend to be large, resulting in a large value of *SSR*.

In the equation, $SST = SSE + SSR$, the total variation is partitioned into two parts, the variation due to random error and the variation due to the linear relationship. The fraction of the total variation that is due to the linear relationship is called the coefficient of determination, or r^2, and is defined by:

$$r^2 = \frac{SSR}{SST} \,. \tag{B-10}$$

r^2 is a fraction that varies from 0 to 1. It will be near 0 if most of the variation is due to randomness, and it will be near 1 if most of the variation is due to the linear relationship.

The closeness to 1 needed for the data to show that the slope is not zero depends on the number of data points. If the dependent data are independent, normally-distributed at each x, with constant variance, and no trend, then the quantity, F, defined by

$$F = \frac{(n-2)\,r^2}{1-r^2} \tag{B-11}$$

can be shown to have an F distribution with degrees of freedom 1 and $n - 2$, where n is the number of data points. When the data satisfy the assumptions except that there is a significant trend, r^2 will be closer to 1 and the computed F statistic will be much larger. Specifically, if the computed F exceeds the upper fifth percentile of the F distribution with 1 and $n - 2$ degrees of freedom, we infer that the data contain evidence that β is not zero, at the 5% level of significance. In this case, we reject the null hypothesis that $\beta = 0$ and conclude that a statistically significant trend exists, with 95% confidence.

As an example, for an assumed set of data fit to the linear model, assume the $r^2 = 0.9369$ and that n is 13. Then the calculated F is 163.3. The upper 95th percentile of the *F(1,11)* distribution is 4.84. Since 163.3 far exceeds the upper 95th F percentile, the linear model is statistically significant. In this example, the data show that it would be very unlikely for a trend not to exist. The linear model explains too much of the variation in the data for a trend not to exist.

Applying the Model to the NMED Data

The method described above was applied for each category of NMED event data, for the overall NMED data, and for additional subgroups of data when trends were found in the overall data. When the calculated F exceeded the 95th percentile, the trend line was shown on the graph and identified as being statistically significant.

In future reports, methods slightly different than that explained above could be employed because the NMED data in many cases does not follow the assumptions listed above. In particular, three considerations apply.

- The data are counts, and thus are discrete rather than being normally distributed. This problem is most pronounced when the counts are relatively low or sparse. Also, normally-distributed data in general can be negative, but the counts are always greater than or equal to zero.
- Variations in counts tend to increase as the counts increase. If the events occur at random, with a constant occurrence rate in a particular year or quarter, then the variance of the count for that year or quarter is equal to the mean or average for that year or quarter. Thus, the assumption of a constant variance for the data in each year may not apply.
- Finally, more than one count can be associated with a single reported incident in a single event category. This situation would occur, for example, if several pieces of equipment fail in an event or if several types of overexposure occur. In these cases, the data are not independent.

One way to address the first two concerns is to identify the number of licensees in various NMED categories and study the event occurrence rates rather than the counts. The rates are more likely to come from a continuum, and might have a more constant variance.

Taking logarithms of the counts and then applying the LS method avoids the problem of possible negative trend lines. The resulting models can be converted back to the scale of the counts after the regression line is identified. In the scale of the counts, the resulting trend, if any, has a slight curvature.

Weighted regression is a method similar to the LS method described above, but it compensates explicitly for the effect of the different variances from year to year.

Another approach that deals with the first two concerns is to apply regression methods that have been designed specifically for counts. Poisson regression, for example, is based on the idea that the data in each time period are counts observed from a Poisson distribution, with an occurrence rate that is described by the model. Given occurrence rates in each time period, and independent counts, the probability of seeing the observed data is easily computed by multiplying the occurrence probabilities for the individual time periods. The slope and intercept parameter estimates are selected so that the model maximizes the resulting "likelihood function."

The third issue may have little effect on the results of a trend analysis, as long as there are many counts with relatively few occurring in clumps, no trends in the occurrence of clumps, and no large clumps of counts coming from a single occurrence report. The best way to address the dependence issue is to identify and remove the duplicate counts prior to the trend analysis.

Appendix C

IAEA Radionuclide Categorization

Appendix C
IAEA Radionuclide Categorization

Table C-1 lists the radionuclides that this report uses to determine the significance for events involving the loss, abandonment, or theft of radioactive sources. This list is derived from the IAEA *Code of Conduct on the Safety and Security of Radioactive Sources (2004)* and from IAEA Safety Guide RS-G-1.9, *Categorization of Radioactive Sources*. Based on the amount of radioactivity involved, the radionuclides are grouped into five categories, with Category 1 being the most hazardous. These categories may be summarized as follows (derived from IAEA Safety Guide RS-G-1.9, *Categorization of Radioactive Sources*):

Category 1: **Extremely dangerous.** These sources could cause permanent injury within a few minutes if handled. Doses could be fatal to someone in close proximity to an unshielded source for periods ranging from a few minutes to an hour.

Category 2: **Very dangerous.** These sources could cause permanent injury within minutes to hours if handled. Doses could be fatal to someone in close proximity to an unshielded source for periods ranging from hours to days.

Category 3: **Dangerous.** These sources could cause permanent injury within hours if handled. Doses could possibly (but unlikely) be fatal to someone in close proximity to an unshielded source for periods ranging from days to weeks.

Category 4: **Unlikely to be dangerous.** These sources would not cause permanent injury, although delayed health effects are possible. Doses could possibly (but unlikely) cause temporary injury to someone in close proximity to an unshielded source for a period of many weeks.

Category 5: **Most unlikely to be dangerous.** These sources would not cause permanent injury.

Table C-1. IAEA Code of Conduct Category 1 through 5 Radionuclide Activity Thresholds

Radionuclide	Category 1		Category 2		Category 3		Category 4		Category 5	
	TBq	Ci [1]	TBq	Ci [1]	TBq	Ci [1]	TBq	Ci [1]	TBq	Ci [1]
Am-241	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Am-241/Be	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Cf-252	20	541	0.2	5.4	0.02	0.54	0.0002	0.0054	1.0e-08	2.7e-07
Cm-244	50	1,352	0.5	13.5	0.05	1.35	0.0005	0.0135	1.0e-08	2.7e-07
Co-60	30	811	0.3	8.1	0.03	0.81	0.0003	0.0081	1.0e-07	2.7e-06
Cs-137	100	2,703	1.0	27.0	0.10	2.70	0.001	0.0270	1.0e-08	2.7e-07
Gd-153	1,000	27,030	10.0	270.3	1.00	27.03	0.01	0.2703	1.0e-05	2.7e-04
Ir-192	80	2,162	0.8	21.6	0.08	2.16	0.0008	0.0216	1.0e-08	2.7e-07
Pm-147	40,000	1,081,200	400.0	10,812.0	40.00	1,081.20	0.4	10.8120	1.0e-05	2.7e-04
Pu-238	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Pu-239/Be	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Ra-226	40	1,081	0.4	10.8	0.04	1.08	0.0004	0.0108	1.0e-08	2.7e-07
Se-75	200	5,406	2.0	54.1	0.20	5.41	0.002	0.0541	1.0e-06	2.7e-05
Sr-90 (Y-90)	1,000	27,030	10.0	270.3	1.00	27.03	0.01	0.2703	1.0e-08	2.7e-07
Tm-170	20,000	540,600	200.0	5,406.0	20.00	540.60	0.2	5.4060	1.0e-06	2.7e-05
Yb-169	300	8,109	3.0	81.1	0.30	8.11	0.003	0.0811	1.0e-05	2.7e-04

Notes

1. The primary values are given in TeraBequerel (TBq). Curie (Ci) values are provided for practical usefulness only and are rounded after conversion.

Appendix D

Revision of Data

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Revision of Data

The NMED is a dynamic database with new reports and revisions to previous reports being added on a continuing basis. This activity can result in additions or subtractions to data that was published in previous issues of this report. Numerical changes in NMED numbers can result from several different types of technical changes to coded data. The most common types of changes to database records are:

- Record additions due to late reporting
- Record additions or subtractions due to changes in event type
- Changes between fiscal years due to event date changes on individual events
- Record additions or subtractions due to changes in event reportability
- Record additions or subtractions due to reclassifying a single combined event as multiple individual events (or vice versa)
- Record deletions due to duplicated records or NRC direction

Figures D-1 through D-9 below display the changes in the data published in the previous annual report. A positive value indicates that records were added and a negative value indicates that records were removed.

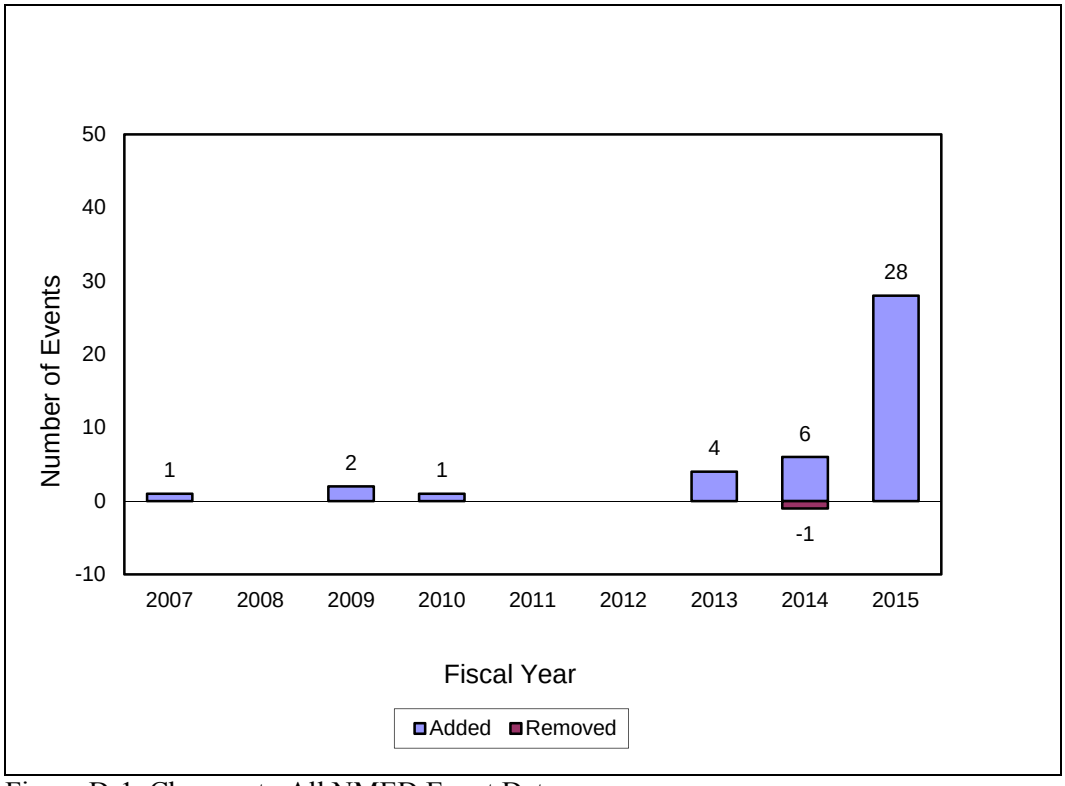

Figure D-1. Changes to All NMED Event Data

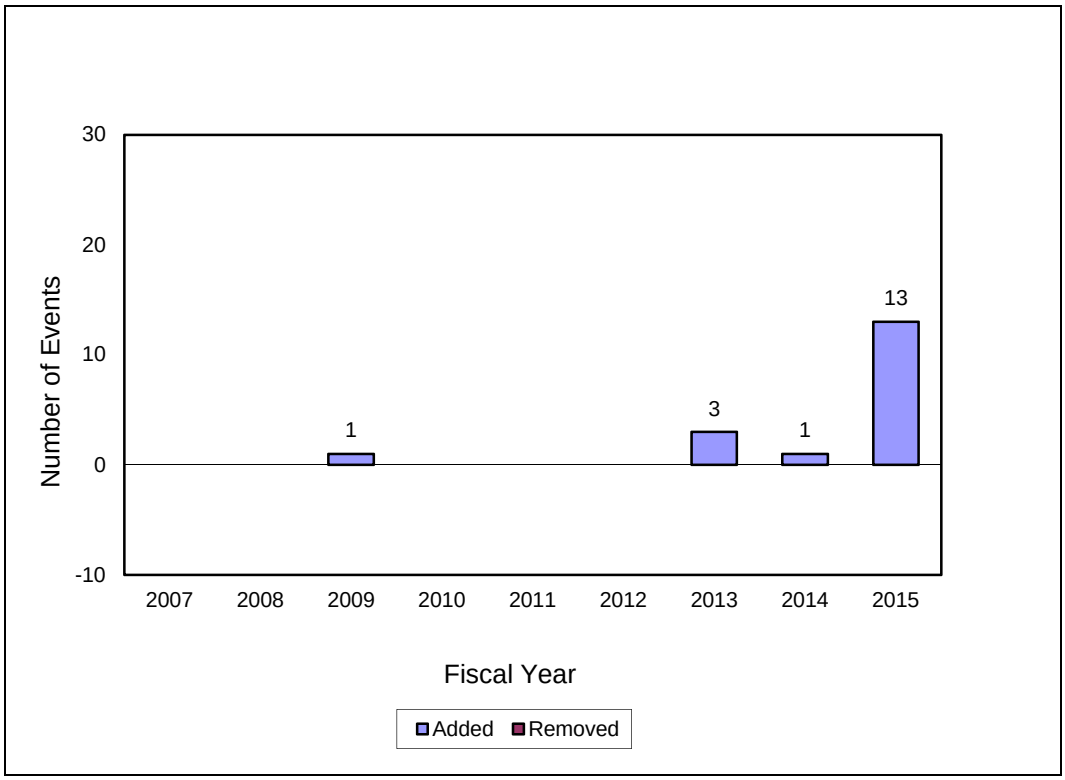

Figure D-2. Changes to LAS Data

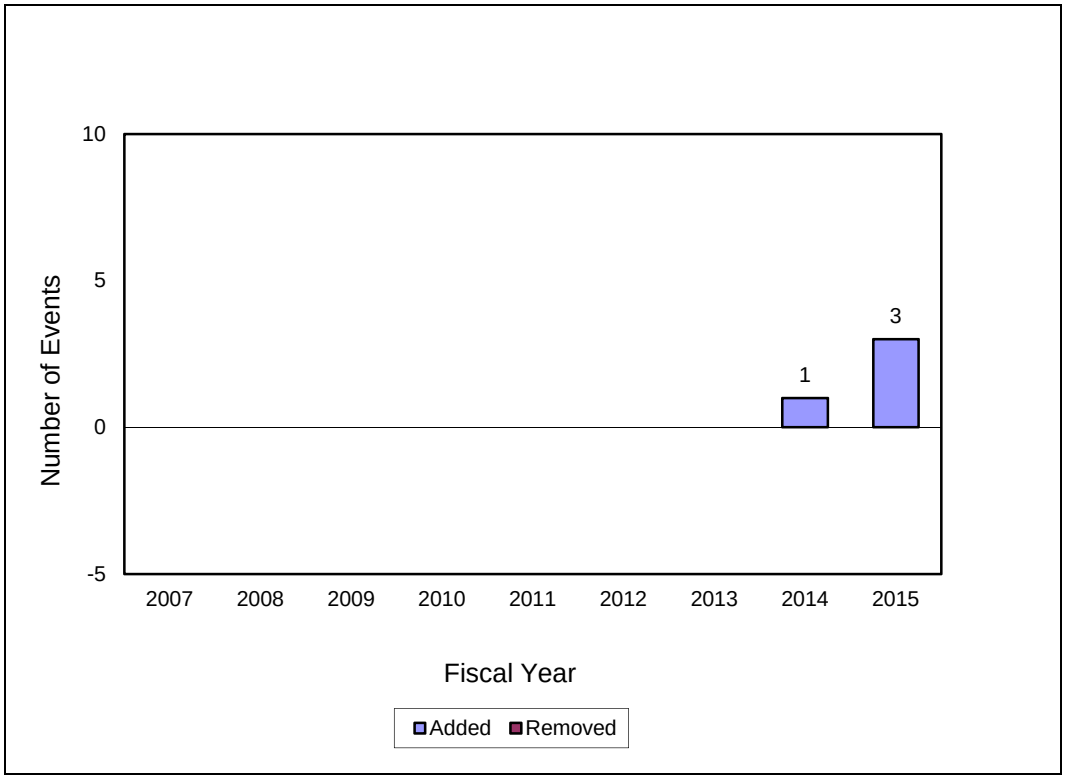

Figure D-3. Changes to MED Data

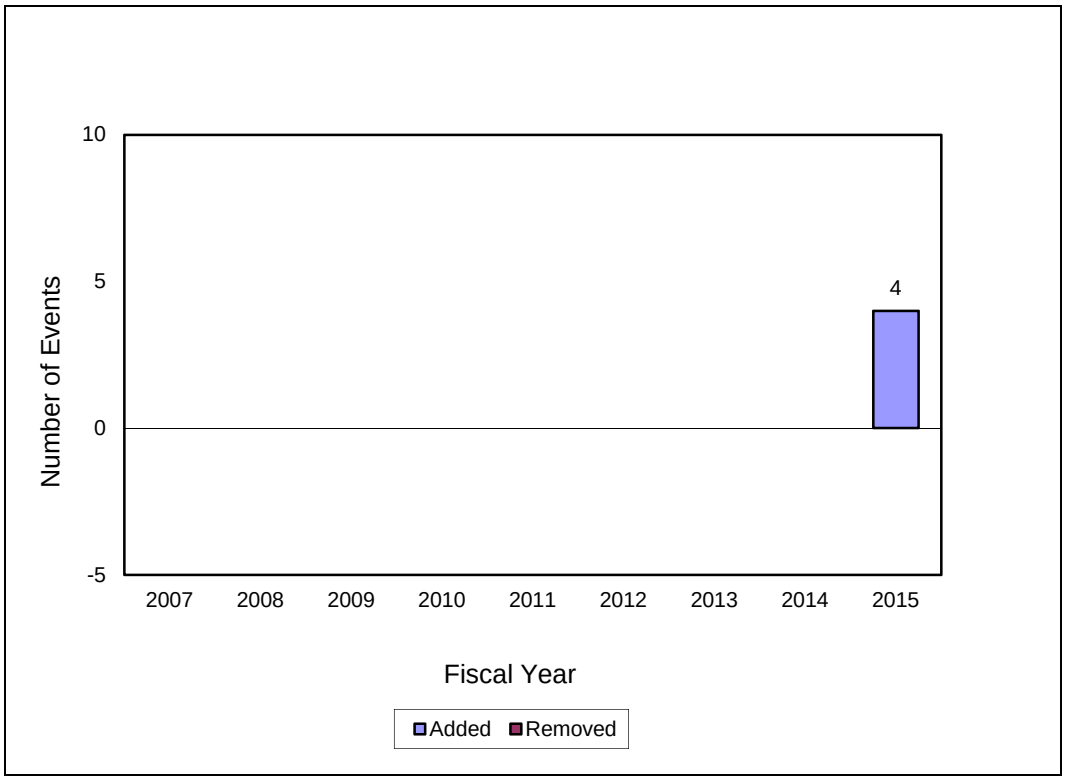

Figure D-4. Changes to EXP Data

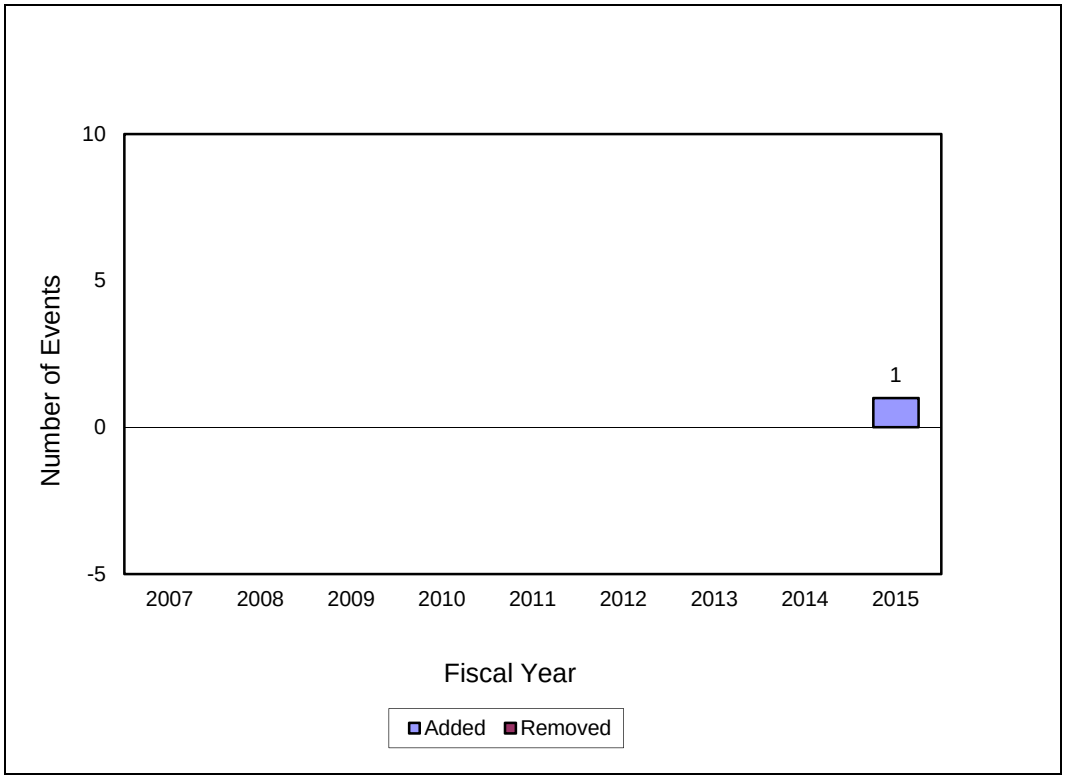

Figure D-5. Changes to RLM Data

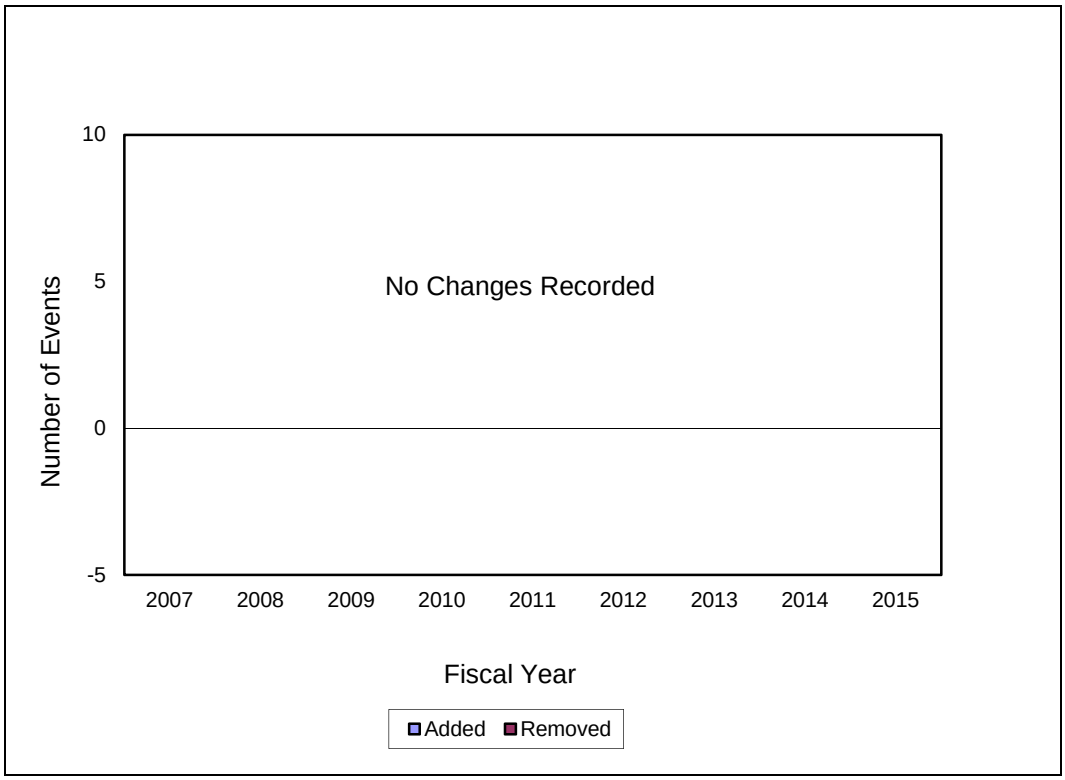

Figure D-6. Changes to LKS Data

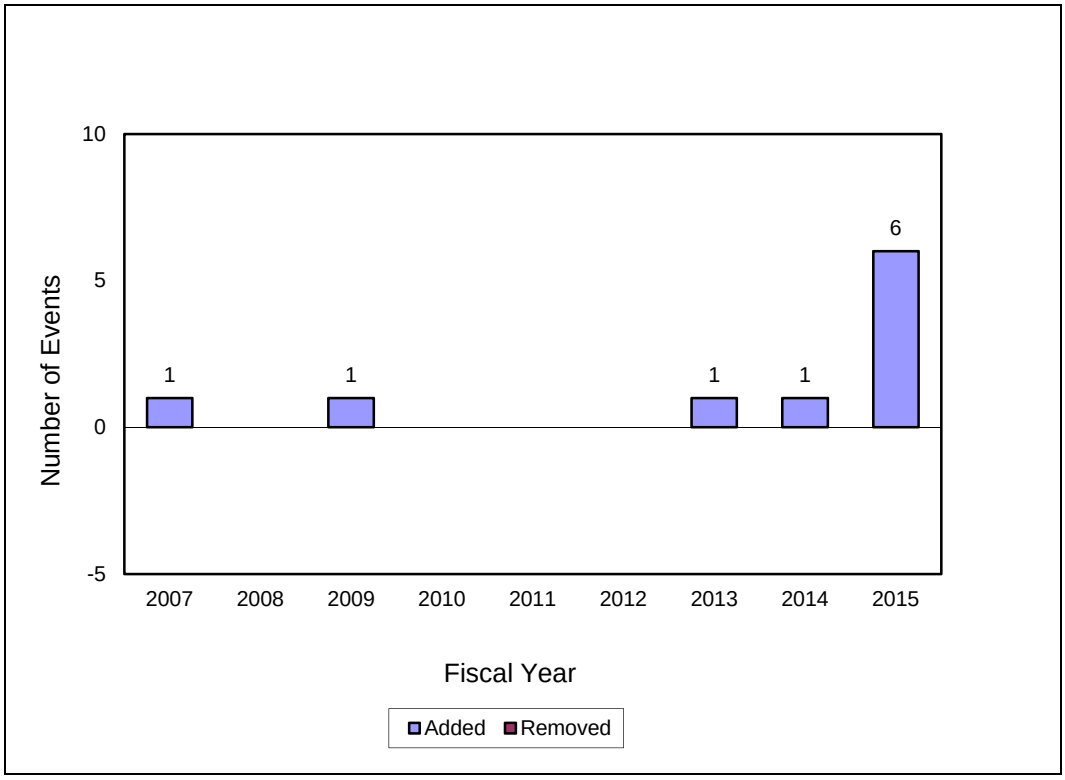

Figure D-7. Changes to EQP Data

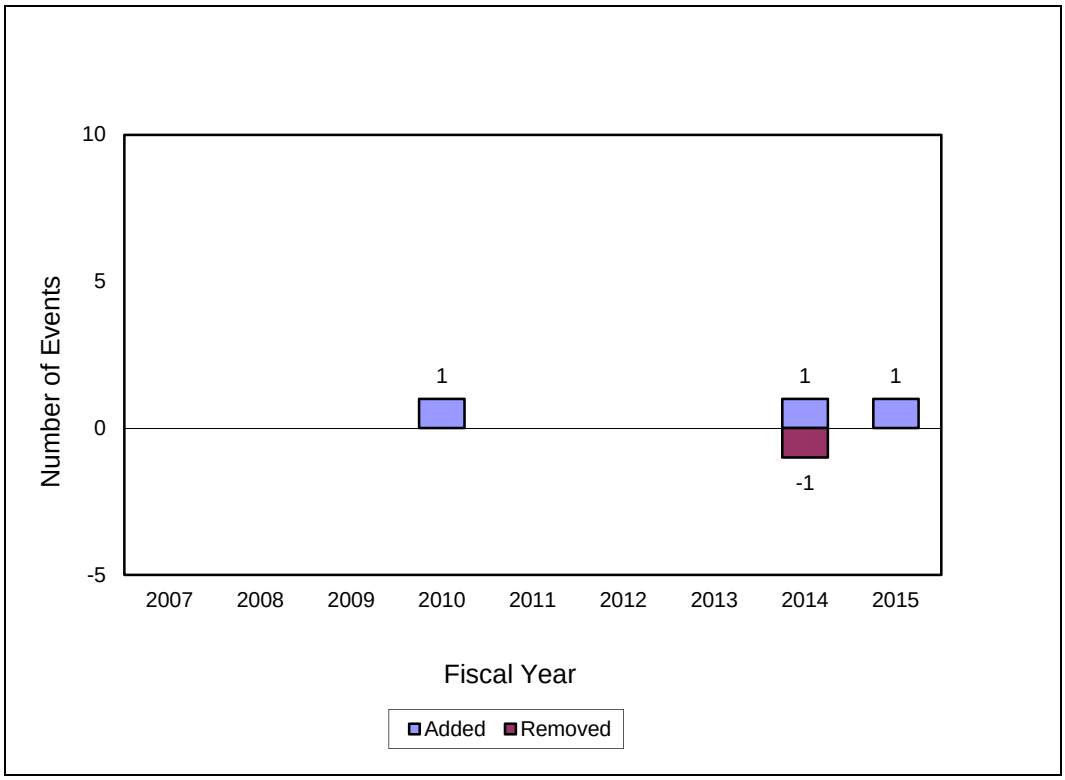

Figure D-8. Changes to TRS Data

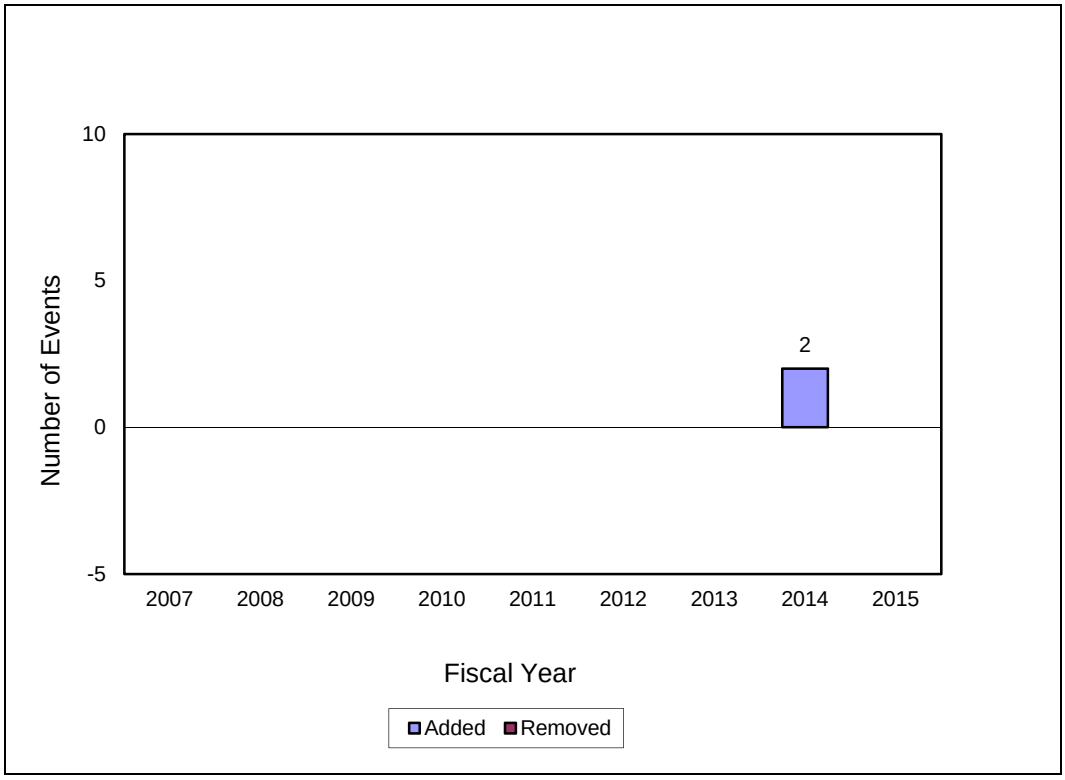

Figure D-9. Changes to OTH Data